PRODUCT ENGINEERING

OCTOBER, 1942

Help Them Win...Turn in Your SCRAP!

Scrap is steel or iron useless in its existing form but valuable as *raw material* for remelting. Since it is already refined, more scrap in the furnace charge speeds up the refining process and enables steel to be turned out faster for implements of war . . . More scrap—*from your plant*—means more steel.

Conservation Authorities Recommend the Following 8 Steps

1. Put some one individual in charge of scrap in all departments of your business and GIVE HIM AUTHORITY TO ACT.

2. Comb the plant and yards for dormant scrap, abandoned equipment, old boilers, pipe, moulds, obsolete dies and parts, material now being destroyed which has salvage value.

3. Survey all plant equipment, particularly idle standby or discarded machines, with a view to applying or converting them to useful production.

4. SEGREGATION: Identify, classify and segregate scrap and supervise its handling to avoid contamination. This will increase its value. Provide separate containers, clearly marked for each class of scrap material.

Repair or rework worn or broken cutting tools. Keep unusable small pieces and turnings segregated. Even high speed steel grinding dust is valuable.

Dismantle discarded equipment promptly into its components — electrical, fastenings, lumber, etc. — so that these parts may be utilized or scrapped.

Sort blanks, short ends, cut-downs, clippings, etc., for possible reuse for smaller parts made in the same or other departments.

Recover and reclaim used cutting oils, lubricants, surplus paints and spray finishes.

Sort sweepings and miscellaneous waste to recover scrap values.

5. Constant reminders in the form of posters, illustrations of right and wrong methods, pay envelope enclosures, house organ publicity, etc., are potent aids to the conservation program.

6. Release for scrap, obsolete engravings, electrotypes, and standing types for catalogs, forms and advertising material.

7. Inspect all refuse to detect avoidable waste and excessive rejections. Educate production executives to correct such conditions at the source.

8. For information and assistance on special phases of conservation and salvage communicate with Industrial Salvage Section, Conservation Division, War Production Board, 9th Floor, Washington Gas Light Building, Washington, D. C., or with nearest regional office.

The metallurgical experience of our technical staff is available to aid you in these and other technical phases of metal salvage.

KEEP SCRAP MOVING INTO WAR PRODUCTION!

THE INTERNATIONAL NICKEL COMPANY, INC. 67 WALL STREET NEW YORK, N. Y.

PRODUCT ENGINEERING

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IN THIS ISSUE

More Patent Reform

As if it weren't already hot enough in Washington, the Senate Patents Committee has been warming things up for patent holders and users in the process of conducting hearings on two bills which would effect violent alterations in the existing patent system. Some of the provisions of the two bills, and of a third proposal submitted by Assistant U. S. Attorney General Thurman W. Arnold, are discussed on pages 548 to 551 of this issue. More next month.

The Know-How Of Flash Welding

Flash welding is okay for fabricating X-4130 steel tubular structures when certain design considerations are carefully observed, recent investigations indicate. Mr. L. W. Combs, of Lockheed Aircraft Corporation, in his article "Tubing and Parts Design Details for Assembly by Flash Welding," relates the advantages of flash welding, enumerates some general design factors, presents a nomograph for determining burn-off and upset allowances when joining tubing, and submits a few graphic examples to illustrate what is considered good design.

Zinc That Sticks in Forming

An improvement on galvanized coatings has been made by American Rolling Mill Company. It enables severe forming and drawing operations of zinc-coated sheets without flaking or peeling of the coating. The production of this material is done by a process entirely different from conventional galvanizing. Turn to page 564 for data on its properties, behavior in fabrication. Use of a chemical treatment for paint adherence is also described.

War Need: Simpler Forgings

In peacetime, economies and cost are the factors which call for simplicity in forging design. But in this kind of a war, where a big forging press is worth

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many times its weight in airplanes and tanks, careful design of forgings is a "must" for speedier production. Correct detailing of draft angles, fillets, radii, web-radius proportions, and tolerances are all-important. Part II of an article that shows you how to design forgings for speedier production begins on page 560 of this issue. Author: O. A. Wheelon, methods analysis engineer of Douglas Aircraft Company. Design data that will prove valuable in the engineering of forgings, including section areas and moments of inertia, are given in this month's Reference Book Sheets, pages 612 to 614.

Warning Note

If Hitler's bombers should ever appear over New York, Detroit, or any of our other big cities, they will find the people ready for them. The people will be warned by big sirens. Not ordinary big sirens. These are terrific. Known as the Chrysler-Bell Victory Siren, and produced at O.C.D.'s instigation. The super noisemaker is powered by a 140-hp. Chrysler engine, and produces 140 decibels measured 100 ft. away. Our "Wartime Designs" editor looked into this siren, and found many interesting details in its design. Chrysler Corporation divulges the complete design story on pages 573-575 of this issue.

New Methods in Ordnance

Many PRODUCT ENGINEERING readers will be truly amazed by the article on page 568 of this issue, wherein J. Barton Nealey highlights the oustanding design and production developments in the manufacture of ordnance materiel. Centrifugally cast guns, cast shells, plastic parts, and other redesigns that are accomplishing the two-fold purpose of faster production and less critical material. Written for *P.E.* by a man who has closely followed ordnance developments for more than 20 yr., this highly authoritative article answers many questions asked by engineers and laymen alike.

Fabrication With Plastics

Merely the knowledge of the physical and chemical properties of the various plastic materials and finished products is insufficient for the man on the drafting board. Therefore Horace C. Hillman, production man at Lockheed, adds to the data presented in September PRODUCT ENGINEERING information on the physical forms of the raw materials available for fabrication of plastic parts, on the methods of producing finished or unfinished parts by molding and casting, and on the fabricating operations which may be required on an unfinished molded part or on solid raw materials. See pages 584 to 586.

Testing With Models

Models, like slide rules, are very handy tools in solving a great number of complicated engineering problems. Some skill in their use, however, is required if the engineer hopes to arrive at the correct answer. H. O. Fuchs, of General Motors Corporation, in his article "Model Tests and Laws for Predicting Performance," page 556, tells why certain laws must be obeyed when conducting model tests. He also tells when liberties can be taken.

What Relay?

Because designers of electrically operated equipment must often choose among many types of devices for protection and automatic control, Westinghouse's R. B. Immel has prepared a chart classifying the common available relays, their principles of operation and the types of service for which they are most suited. These relays are operated not only magnetically but also by thermal, mechanical, chemical and other means. The first section of this chart is presented on pages 591 to 596 of this issue. Next month six more pages will be presented.

Vibrations in Mechanical Systems

The usual method for computing the vibrations produced in mechanical systems by impressed vibratory forces, initial displacements or shocks, is by means of differential equations for which constants of integration must be determined to suit the initial conditions. C. R. Freberg, of the school of mechanical engineering of Purdue University, in his article which begins on page 588 shows how to solve vibration problems by means of the mobility theory. The calculations involved follow closely those used by electrical engineers in solving electrical network problems.

Photos Break into Engineering

Recent developments in cameras and light-sensitive emulsion materials have made photography an essential engineering tool in design, research, and many production procedures. The extent to which photography can help engineers is limited only by the imagination and the ingenuity of the engineer. The article beginning on page 598 describes some comparatively new photographic methods and their application in making drawings, templets, patterns and records that should stir the reader into studying how his problems could be simplified with the use of photography.

PRODUCT ENGINEERING

WHAT'S COMING

The "Whys" of Shell Design

A shell, merely the steel body that carries the explosive and fuse, is in appearance perhaps the simplest thing in the world to design. Actually it is a highly critical element, subjected to tremendous forces. Unless every little detail, from the base cover to the notches that lock the fuze cap in place, is made within specified tolerances, results may be disastrous. What happens when a shell is fired, the magnitude of forces developed, and the explanation for each dimension and tolerance will be set forth in next month's issue. Sketches and diagrams will tell most of the story.

Photostat-Tracing

As a sequel to the article "Photo-Tracings" which appeared in January of this year, Lester C. Jones of Lockheed Aircraft Corporation will present in November a second article dealing with photostat-tracing—the latest development in photography to speed routine work in engineering departments.

Electrical Analogues

For the solution of many engineering problems in which a direct or mathematical answer cannot be easily obtained, E. N. Kemler will present next month an article showing how to use dimensional analysis approach, analogies, and mechanical models. Mr. Kemler will show how many different physical phenomena can be represented by similar equations, thus permitting the results found in one field of science to be applied in some other field.

Cost of Forgings

Following up the articles in this month and last month on "Design of Forgings for Speedier Production," PRODUCT ENGINEERING for November will publish the results of Douglas Aircraft Company's extensive study of forgings costs. Upshoot of this study are charts and tables by which the cost per piece of a forging can be predicted with reasonable accuracy. The data is in use by the Douglas design staff, and should be valuable to you.

The Chemical Engineer cuts years to months...

Born in the turmoil of the last war, he is shaping a new world with mighty swords and magic plowshares

GERMAN CONSUL-GENERAL HOSSENFELDER, writing from New York on March 3rd, 1916, to von Bethmann-Hollweg, chancellor of the Imperial German Government, confidently predicted defeat for the United States because we were totally dependent upon the great chemical industry of Germany. "Americans," he wrote, "can never establish such an industry. They have the resources but they lack the necessary science and technology. And, besides, the conflicting selfishness of American business renders it impossible."

Even before the ink was dry on Hossenfelder's letter a new figure appeared on the industrial scene—the American chemical engineer. With the help of patient, but progressive and venturesome capital, he laid the foundations for the largest and most resourceful chemical industry in the world.

Today he is an all-important figure. For we are fighting a chemical war, even though the emphasis that is placed on planes, tanks, ships, guns and other armament tends to obscure that fact. And this chemical engineer is waging war for us on a prodigious scale. Bombers carry more tons of more deadly explosives because he has developed stronger and lighter alloys and more efficient fuels. Tanks are better armored and wield heavier blows because of products and processes born in chemical laboratories. Ships are welded together by new metallurgical techniques that save precious months over older processes. Gun barrels that are made in minutes instead of hours shoot farther and faster because of better ammunition.

And quantity keeps pace with quality. By mid-year of 1942, explosives were being produced in newly constructed plants twelve times faster than a year ago. Smokeless powder output has been doubled since December. Five times as much TNT was being made in July as in the months preceding Pearl Harbor. One single new plant produces more of this high explosive than did the entire pre-war industry—and several of these plants already are in production.

By what Major General William N. Porter, Chief of the Chemical Warfare Service, calls a "miracle of production," the sort of incendiary bombs that General Doolittle's lads showered on Tokyo were rolling out of our plants within a few weeks after we got into the war. As General Porter puts it, "they were rolling not by hundreds or even thousands, but by the millions." That record he has cited as a tribute to the "ingenuity, industriousness and patriotism" of the American chemical industries.

Yet the General agrees that we have only started to produce in the tremendous volumes that will shortly make Germany, Italy and Japan "revolve on their boasted Axis." Our newest plants are just coming into production. They face no limiting shortages of materials for, in the main, our chemical industry draws its strength from coal, salt, sulphur, limestone, oil, natural gas, coal-tar, air and water—all available in abundance.

We have heard little about the use of poison gas by our enemies. It may be that good reasons for this are stored away in our well-stocked chemical arsenals. American chemical manufacturers have worked hard and long with our armed forces so that if the time ever comes to make good on the President's warning of retaliation, America will be more than ready.

And defense against gas has not been overlooked. Every soldier is equipped with a most efficient type of gas mask, developed through twenty-five years of intensive research. The Chemical Warfare Service already is manufacturing millions of masks for distribution to civilians. Let us hope we may never have to use them. But if we must, we need have little fear of any gas or secret chemical.

This gas mask program has been made possible by a literal metamorphosis of production facilities, as peacetime industries have been converted to war purposes. A lumber company, for example, is making activated carbon from sawdust. Novelty manufacturers of rubber goods are turning out valves and assembling other parts. Former manufacturers of shirts, swim-suits, shoes and beds have converted their facilities and are contributing their share. More than eleven hundred contractors and two hundred and fifty sub-contractors are supplying their full quotas of chemical warfare materials. And production is right up to schedule.

But the bulk of the war job of our chemical industries has to do with items other than weapons and

ammunition. The German Consul-General, in that 1916 report to Berlin, said that many American industries were in a critical condition because of the scarcity of German chemicals. He related in particular that "the cries for help from the world of physicians are becoming louder and louder and more and more insistent." Thanks to our chemical industries this cry no longer is heard. Even though we are again cut off from quinine, camphor and some other strategic medicinals, our homes and hospitals are adequately supplied with synthetic products. Most of these are better and cheaper than the natural materials. The same sulfa drugs that have saved so many civilian lives in recent years have gone to war, with the result that deaths from infection at Pearl Harbor and Bataan are reported as surprisingly low. In this war we suffer no shortages of iodine and potash. Pioneering research in the field of vitamins has led to new industries that are contributing to health and better nutrition.

Those new uniforms the soldiers are wearing are of better quality and will last longer than the shoddy, ill-fitting outfits of 1918—thanks to sunfast dyes and new man-made products. And in the field of fabrics, nylon and the new rayons have gone to war in parachutes and super-strong cords for tank treads and tires.

* * * * *

And that brings up the question that 30,000,000 American motorists are asking with ever increasing concern. "When, Mr. Chemical Engineer, are you going to give us a set of new tires for the old family bus?"

That, I am told, is just what the chemical engineers have set about to do on a scale that is difficult to comprehend. In the words of Raymond Clapper, the columnist, "the synthetic rubber program for this year and the next is the biggest job of chemical engineering ever undertaken in the world." A billion dollar industry is being built at record speed to make almost a million tons a year of chemical rubber to serve our war needs and those of our allies. This cannot be accomplished overnight. Many months are required to design and fabricate complex equipment, much of which must be made from corrosion-resisting metals and alloys. We shall be lucky if a tenth of the desired capacity is in continuous production this year and even more lucky if, by the end of next year, the new industry should be turning out synthetic rubber at a rate of 875,000 tons—using both petroleum and grain as raw materials.

All this, of course, must go for essential military uses but there is reason to believe that in the laboratory and pilot-plant stages we have some promising substitutes and stop-gap materials that may tide us over until the big program starts rolling.

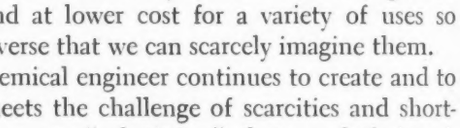
The present prospect of real success is possible only because of the cooperation of the chemical, rubber and petroleum industries. Individual firms and entire industries have set aside their normal desires and selfish interests to pool their patents, share their research and engineering developments for the common good. Synthetic rubber is here to stay as the basis for a great post-war industry: no doubt as to that lingers in the minds of the men who have seen many other natural products—indigo, alizarine, camphor, vanillin—all eventually fall before the ingenuity of the chemical industry.

* * * * *

In the coming peace to which we look forward hopefully, we shall find a new world full of new materials, new conveniences, new jobs, new opportunities, all stemming out of the present-day work of the chemical engineer. The same tough, transparent plastics that now make noses for bombers will give us new frameless windows for our homes and automobiles. With capacity to produce at least 2½ billion pounds of aluminum, which is five or six times pre-war production, and a magnesium capacity 50 or 60 times the pre-war figure, many new uses will develop for these structural materials of great strength and amazing lightness. Almost anything that flies, runs, moves, or otherwise is motive, will have a place for them. New fibers such as nylon and vinyon had scarcely got started before they were put to war use. Once the war is over they will be with us in greater abundance and at lower cost for a variety of uses so vast and so diverse that we can scarcely imagine them.

And the chemical engineer continues to create and to invent. He meets the challenge of scarcities and shortages with ever new "substitutes" that excel their originals. Even before the war is over he will have placed at our command a hundred new materials which we did not have before. His workshop is all industry. His contributions are as limitless as are our needs.

But right now his all-important job is to help win the war; to fight to a finish the ruthless and resourceful enemies that are devoting all their science and technology to bring about our defeat. So, as we take stock of our assets in this desperate struggle, we count among the first the proved resourcefulness of the research-minded chemical engineers we now have mobilized to help us fight this chemical war.



President, McGraw-Hill Publishing Company, Inc.

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PRODUCT ENGINEERING

GEORGE F. NORDENHOLT, *Editor*

"In the Public Interest . . . . ?"

Perhaps because the department of justice, presumably backed by the administration, has found it impossible to get very far in its attempts virtually to nullify patent protection through new legislation, a less direct but more vicious method of attack has been adopted. Companies are being indicted under the anti-trust laws for patent pooling, market restriction and price fixing of patented products. The indictments usually are accompanied by the accusation that "exorbitant" prices are charged for the patented product and that it is therefore "in the public interest" to prosecute.

"In the public interest" is a sweeping phrase, a claim that often does not bear close inspection. "In the public interest" R.C.A. was accused of "monopolizing" radio patents by buying most of them. By this means R.C.A. was able to reduce and did reduce the royalties per radio set from a hundred dollars or more to a nominal sum. Today a good radio costs less than the royalties per set formerly totaled, but R.C.A. was threatened with a suit "In the public interest".

The incandescent lamp is now many times more efficient than the lamp of 1900 and has many times its life and power. Its price has been reduced from more than $2.00 in 1900 to 15 cents today. "In the public interest", the department of justice wants to make it impossible to repeat that performance in the development of fluorescent tubes by indicting companies which have been pooling their research and patents to perfect fluorescent tubes. "In the public interest," Standard Oil was indicted for its patent arrangement with I. G. Farbenindustrie, but that patent arrangement enabled Standard Oil to be now one of the major producers of many well-nigh priceless materials. Because the Rockbestos Company fixed the selling price for its patented cable produced under license by several manufacturers, all the companies were indicted "in the public interest" for price fixing and collusive bidding.

Dozens more similar instances wherein the department of justice is attempting through indictment under the anti-trust laws to eliminate the privileges, advantages and value of patent protection can be cited. Ironically, ownership of a patent is rapidly becoming a liability rather than an asset. Under the leadership of Assistant Attorney General Thurman Arnold and with the acquiesence of the administration, organized research, pioneering in industry, aggressive leadership in the development of new materials, new products, and new scientific knowledge, will be throttled, perhaps killed. "In the public interest," misguided political leaders would relegate these United States to industrial and scientific inferiority because they cannot bear to see "plus" profit on patented products. They ignore the fact that a large portion of the profit goes to pay for research, the profit from one invention often being needed to pay for the losses incurred in a dozen other developments which were expensive but failed.

Nor do these political leaders consider the cost of unearthing abstract scientific knowledge which has no direct value but which provides the foundations for subsequent discoveries.

Investigations, threats, indictments and anti-trust suits are already hampering research and effectively discouraging invention. It is certainly not "in the public interest" to confiscate the incentive, provided for in our Constitution, for unearthing new knowledge, inventing new products and contributing to scientific progress. But such confiscation is what is being attempted today, by our government—"in the public interest".

Senate Committee Undertakes Patent Reform By Confiscation — I

First of a series describing and evaluating efforts at patent reform in 1942. Compulsory licensing, one of the foremost principles which the lawmakers are considering as a check on patent abuse, is described in this article, along with a bill which would give the government power to license or take patents in war or in a national emergency.

OUT OF A WELTER of headlines—carefully manipulated to trumpet the charge that big business is "holding hands with Hitler" and to throttle the reply that patent cartels have blessed America's war effort—is evolving the New Deal's program for patent reform.

Publicity, compulsory licensing, broadened use of antitrust prosecution, nationalization of patents, federal intervention into patent infringement suits, license control and restrictions on infringement and recovery suits—these are the broths brewing in the pot tended by the U. S. Senate Patents Committee which has been and probably again will be brought to a noisy, front-page boil.

Currently, the committee has two bills before it, Senate 2303 and Senate 2491. Although neither has yet been voted upon, formally or informally, consensus is that each, as it stands, is dead. The principles of which they are composed, however, are not dead, and any or all of them will be incorporated into whatever measure the committee reports.

A third set of principles was laid before the committee by Assistant U. S. Attorney General Thurman W. Arnold, who has been and is ever-ready with new faggots for the flames licking at the patent system as it exists today. If the U. S. Justice Department has anything to do with the final bill reported by the senate committee—and there is no reason to believe that it will not have a great deal to do with it—most or all of Arnold's provisions will be included.

Current attempts to end patent abuse fall into several categories, of which two are all-surpassing in importance. One of these seeks to use compulsory licensing as the lever to pry patents free of unhealthy control. The other, most ardently espoused by Arnold, seeks to tie patent control into enforcement of the antitrust act.

Compulsory licensing, Senate 2303, and other less drastic proposals will be discussed in this article.

Senate 2491 is aptly described by the Boston Patent Law Association as the "more serious" of the two bills. It is not an emergency measure but will operate during peace or wartime. While it is replete with drastic provisions, it is chiefly a vehicle for compulsory licensing. The act makes all patent grants subject to these conditions:

1. If the patent commissioner finds that a patentee has failed for three years after the patent was granted to make, use and vend his invention without reasonable justification, or
2. If he finds that there has been such failure and that the patentee has refused during that three years to allow any other person to make, use and vend the invention for just compensation, and
3. If the commissioner further finds that such failure or refusal has resulted or is likely to result in a violation of the antitrust law or is otherwise detrimental to the public interest, he may order the patentee to make the invention public on such reasonable terms as the commissioner may stipulate.

Any interested person may allege such failure, whereupon the patent commissioner shall conduct a hearing to determine the facts. If the allegation be sustained, the commissioner shall order the invention made public and shall prescribe the terms under which that action must be taken. Review of such decision may be had from the Court of Customs and Patent Appeals or federal court in the District of Columbia.

This then, is the compulsory licensing provision which has been so fiercely championed by government men and so bitterly assailed by patent attorneys and business men. Its terms are drastic, to be sure, but not in comparison to Thurman Arnold's suggestion for accomplishing the same end, i.e., breaking up "log jams" of patents by which inventions may be suppressed to retain control of an industry or a market in the hands of a select group.

Arnold's method of dealing with the matter is contained in one sentence of his proposal, and would:

Render illegal any patent use, including unreasonable failure or refusal to grant licenses thereunder, which unreasonably limits the supply of any article moving in interstate commerce.

Penalty for such action would be a fine of $5,000 and/or a year in jail. Also, any judgment or conviction under this section would nullify the patent. No criminal prosecution would be taken if the patentee had, before he took any action which might later be attacked, outlined his plans for development of his patent to the Attorney General in writing. Such preliminary written explanation, however, would not prevent the Attorney General from bringing civil suit to enjoin practices listed in the plans which he considered in violation of the section.

Arnold's provision is obviously more severe than that in Senate 2491. For one thing, the latter merely provided that patents unreasonably restrained must be licensed. Arnold makes the practice subject to a criminal penalty. Senate 2491 gave the patentee three years in which to manufacture, use and sell his invention before compulsory licensing would be considered. Arnold sets no time. Senate 2491 requires that the failure to make, use and sell the invention be judged unreasonable before compulsory licensing be invoked. Arnold gives no such protection.

Presumably, a manufacturer whose product meets rapid public approval might be unable to keep up with the mounting demand. Under Senate 2491, he would surely not be considered to be restraining the invention unreasonably if he made every effort to catch up with the demand. Under Arnold's provision, the mere fact that he was unable to supply the demand might be held to be restraint of trade. At least, there is nothing in the act to prevent such a construction of the situation, and the only protection against it the patentee would then have would be the good nature of the Justice Department attorney assigned to the case, who might or might not view the situation as an honest one purely a result of chance.

Arnold's provision could subject any patentee who failed to license or manu-

facture his patent to an investigation to determine whether he was holding up the supply of the commodity in interstate commerce. If this could be demonstrated to the satisfaction of the prosecutor, and if the failure were judged by the prosecutor to be unreasonable, then the patentee would be open to criminal action, with his patent rights at stake and a heavy fine and jail sentence at the end of the road. The prosecutor in any such case would be an assistant attorney general, politically-appointed and owing his job to the administration then in power. The administration might or might not be anti-business in its general attitude. Conceivably, such a prosecutor might use vastly different standards to determine whether interstate commerce had been adversely affected than would a manufacturer.

Granted that each party would consider its case valid and that courts are provided to supply equitable decisions in such disputes, the fact remains that such an action would be considerably more burdensome on a patentee whose patent and the business built on it, whose reputation and whose very liberty depended on outcome of the suit, than on a prosecutor whose entire responsibility would be to the administration then in power.

Even if the patentee were to be freed of all worries about criminal prosecution by explaining his proposals in writing to the Attorney General before embarking on them, he would still be under threat that at some future date the department might construe his plans as a violation of the section and ask that they be enjoined. In such a case, all the patentee's efforts in the development of his patent as a business property would be under fire, faced with disestablishment or drastic revision if the government won its case.

Arnold's method of allowing the patentee to keep himself free of criminal prosecution is not so foolproof as it might seem. Explaining it to a friendly Senate Patents Committee, he was far from explicit as to its detailed workings. It was his opinion that the mere fact that a patentee had filed a complete written statement of his development plans would suffice to outlaw criminal prosecution for any act thereunder, regardless of how long the department delayed decision on the plan.

He agreed, however, that no subsequent administration of the justice department would be bound by such implied "gentleman's agreement." Thus, should the bill become law, patentees who filed their development plans in writing would be subject to criminal prosecution by any subsequent attorney general who determined that the patentee's proposal violated the act if that attorney general did not consider himself bound by a precedent laid down by his predecessor.

The whole method is not without honored precedent, however. Years ago, several coal companies, representing only a small percentage of the market, banded together to stabilize operations in a manner which bordered upon violation of the antitrust law. A federal court approved the plan when the companies submitted it to determine its legality. The approval was based on the fact that the agreement offered a solution to grave difficulties facing the companies and that the operations were so limited that they could not, as contemplated, subject the industry to ruinous malpractice. However, the court kept jurisdiction with provision for periodic re-examination, and warned that if the plan were extended to a point where it threatened or affected the public interest, it would be revoked. The principle in this case is the basis of Arnold's plan to allow the justice department to keep its fingers on patent manipulation through the antitrust act.

Proponents of the Arnold school of thought see compulsory licensing, no matter how it is administered, as a means of preventing suppression of inventions, and of breaking up patent cartels, domestic or international, which are aimed at dominating the market, fixing prices and elbowing competitors out of the field. Beyond doubt the principle would do just that in many cases.

The principle has its disadvantages, however, and unbiased study of both sides of the question leaves grave doubt that whatever good the principle might do would suffice to offset the harm it could do.

Obviously, ownership of a patent does

Westinghouse Electric & Mfg. Company

Even in wartime, the nation's research bill is tremendous. In 1938 alone, six major companies spent more than $6,500,000 on research performed with equipment which cost more than $8,000,000. Costs incurred in such laboratories as this may be recovered only from the "plus" profits afforded by patent protection. Pending legislation, which seeks to "normalize" profits, would cripple research

not assure the holder of a fortune or even a modest profit. It merely entitles him to specific protection in the development of the patented commodity and to specific means of recourse if that protection is violated.

When a patent is issued, its holder often faces years of development before the device is ready for public consumption or before it is sufficiently perfected, popularized and publicized to command any market. Such development takes money, and its cost, added to the expenses incurred in discovering and patenting the commodity or process, determines the amount which the investor must recover merely to break even on the invention.

Now if a competitor be allowed to demand a compulsory license from a patentee who has spent three years in getting his product on the market, and if such license be granted on the patent commissioner's terms, the patentee may indeed be in grave straits. Perhaps the commissioner will consider the investment to be recovered in setting the royalty under which the compulsory license will be granted, and perhaps he will not. Perhaps he will set a royalty which will provide for amortization over a longer period than that for which the patent is valid. Perhaps he will consider whatever disparity exists between the ability of the patentee and the prospective licensee to manufacture at low cost. Failure to consider this could ruin a small patentee.

Whatever his basis for setting the royalty, it is not improbable that if this principle becomes part of the nation's patent law, a patentee may find himself forced to license a competitor who will be in a position to undersell him. If that constitutes protection, then a great many people have been wrong for many years.

Of course, the patentee has the right of appeal from decisions by the patent commissioner, and certainly if he can not get justice in the courts, his patent and all patents are worthless. However, court action is costly, lengthy and wasteful of time and energy which can be used more profitably elsewhere.

Furthermore, such appeals would go into federal courts for the District of Columbia or into the court of Customs and Patent Appeals, each of which might have a different idea of what constitutes a reasonable justification for failure to make, use and vend a patent. The circuit court of appeals is the next step in resolving any such question and the Supreme Court the final one. Access to the latter is not easy.

Another weakness of the compulsory licensing principle is its effect on the value of a patent. Conceivably, a prospective purchaser of a patent or a prospective licensee would be less willing to purchase or pay well for a patent encumbered by one or more compulsory licenses than he would for an unencumbered patent.

City zoning ordinances are among the most jealously-guarded laws. Patent holders would do well to guard the patent laws as closely as property owners guard zoning laws, lest similar destruction of patent property values be legalized.

These possibilities would be withheld for three years under Senate 2491, and if compulsory licenses were granted under that measure, the patentee would still hold title to his patent. Arnold's measure would allow these possibilities to arise at any time, and would nullify the patent and impose a fine and jail sentence for substantially the same activity.

Another provision of Senate 2491 prohibits a patentee from bringing suit for infringement against a seller or user of any patented device unless the patentee has first won a decree against the manufacturer or supplier which holds the patent valid and infringed. Likewise, no suit for contributory infringement may be heard unless the plaintiff shall have obtained a decree against the primary infringer.

This section, in effect, prevents a patentee from sidestepping suit against an alleged infringer who may be a powerful court opponent in favor of a suit against a less powerful user of the alleged infringing product.

The section can have both beneficial and adverse results. The present method, patent attorneys agree, does sometimes result in cheap validations for patents and can be an instrument of ruthless business practice. For instance, a patentee who can muster all the resources for a lengthy legal battle may employ a multiplicity of suits against small users to drive business away from a powerful competitor who may be crippled more easily in this fashion than in court. Outlawing this procedure would be beneficial, particularly insofar as it halted the practice of obtaining a court decree holding a patent valid by suing a user who is unable or unwilling to spend the time and money to put up a real defense.

Conversely, large and powerful companies may have less hesitancy in infringing the patent of a small holder if this provision becomes law. Obviously, the small holder would be at a greater disadvantage in an infringement suit under the requirement forcing him to sue the powerful manufacturer or supplier of the infringing product before suing a small user of the infringing product. Furthermore, the patentee must sue in the United States court having jurisdiction, which could mean that a Californian might be forced to present his case in New York. Thus, the provision can work both ways.

Principal aim of Senate 2303 is to free patents for the nation's best use during time of war or declared national emergency. The bill may not operate, except indirectly, at any other time. Few people will quarrel with the government's right to take those steps it considers necessary to preservation of the country during war. Perhaps, then, the bitter condemnation accorded this bill is due to its companionship with Senate 2491, a vastly more far-reaching act.

Under 2303, the President may, when

Senator Joseph C. O'Mahoney, Wyoming Democrat, has taken an active part in the hearings held by the Senate Patents Committee although he is not a member of it. Here he is shown shaking an accusatory finger at F. A. Howard, vice-president of Standard Oil Company of New Jersey. O'Mahoney charged that the company's cartel agreements with I. G. Farbenindustrie left it "bound by two loyalties," a charge Howard denied

he finds during war time that manufacture under any patent is necessary for national defense, issue a declaration which will free the patent for general use. This declaration serves as a general license to any person who may choose to enter the field, and no operation begun under such declaration may be enjoined. The patentee's only remedy is to sue for a reasonable royalty.

After such declaration, the president may, if he so chooses, license any specific manufacturer under any patent he has freed. The terms of such specific license shall include the royalty which the President shall consider reasonable, the duration of the privilege and such other terms as he may stipulate.

In this event, the patentee may collect his royalty or sue if it is not paid, but no court may award him a greater royalty than that established by the President. All defenses in such suit are available to the defendant, and the government does not guarantee any royalties. Treble damages which are now available from infringers, of course, are outlawed.

The dual provisions of this section may operate independently or together. As explained by a Justice Department representative testifying before the Patents Committee, the provision for issuance of specific licenses after a declaration freeing the patents concerned will tend to stimulate operations under patents previously restricted by assuring the licensee that he will have to pay no more than a specified royalty per unit and that he will have a definite length of time in which to operate under the patent. These assurances, which are lacking under the general, declaratory license, presumably would satisfy the prospective patent user's concern over amortization of his investment and the final profit therefrom.

Certain patent attorneys feel that without some limitation on the length of time during which a declaratory or specific Presidential license shall be valid, the bill provides an entering wedge for ultimate nationalization of patents or compulsory licensing. These attorneys would like to see the life span of such licenses definitely limited, preferably to the duration of the war.

Senate 2303 also provides that the President during time of war or national emergency may acquire patents by purchase, donation, taking or otherwise. Holders of patents taken in the interest of the war effort may sue for compensation in the Court of Claims, an agency which some patent attorneys dislike as being too slow-moving, and from which there is no appeal save to the Supreme Court in some cases.

When questioned as to the point of the section by the Senate Patents Committee, a Justice Department attorney explained that it "may be found useful in certain situations in which the power of compulsory licenseing may prove to be inadequate. . . . One of the real needs for this provision is that you want a quick, sure way of getting patents out of the control of persons that you deem inimical where you are not in a position to establish that they are enemies."

In fairness to the witness who made the statement, it should be pointed out that the topic under discussion when the statement was made was the control allegedly exercised over American industry by international patent cartels, notably German cartels, in that twilight of American peace between September 1939 and December 1941. The explanation fits that situation admirably, but it is phrased in terms so broad that it might naturally cause misgivings in the minds of patentees in any future national emergency.

Principal justification for approving this bill is to be found in the contention of Attorney General Francis Biddle that present legislation turning patents over to the government in time of war is insufficient. Patent attorneys deny this vehemently, citing the act of 1910 which gives the government the right to use any patent without fear of infringement during wartime. This right was extended in 1918 to cover work done for the government during wartime as well as that done by the government. Enemy-controlled patents may be taken over and thus freed for the use of the government.

Biddle raised the question, however, as to whether existing laws would cover work done for allies of the United States. It is to be presumed that the courts would not seize upon a technicality on which to take a stand that could endanger the war effort. However, there can be little doubt that the President considers his lend-lease victories too dearly-bought to subject them to the uncertainties of legal action if he suspects that the courts might so rule. Filing of any great number of suits on this issue could translate any such administration fears into action.

Provisions for publicity on patent transactions are regarded as certain of inclusion in whatever bill the committee finally reports. Senator Homer T. Bone, of Washington, chairman of the Senate Patents Committee, chose that point on which to make a definite statement regarding makeup of the final bill. Said he as early as mid-August:

"The committee right now would agree to this much: that there should be a proper recording of all patent cartel relationships, and the contractual basis for each, with some public agency, possibly the department of justice."

Arnold would require all patent sales, transfers or license agreements to be recorded with the attorney general. Senate 2491 stipulated the Federal Trade Commission as repository for all such documents, but that provision was generally regarded as ineffectual. Idea behind both these suggestions is to provide a public or semi-public file in which patent transactions will be available to government officials to determine whether or not provisions of any of the proposed legislation are being violated. This measure has particular point in view of several provisions regarding the antitrust nature of patent abuse which will be discussed next month.

President William S. Farish, of Standard Oil Company of New Jersey, insists that the company's contractual relations with I. G. Farbenindustrie, German manufacturing trust, did not hamstring the U. S. war effort, but that they "did inure greatly to the advance of American industry and more than any other thing has made possible our present war activities in aviation gasoline, toluol and explosives and in synthetic rubber itself"

Detail Design for Joining By Flash Welding

L. W. COMBS, *Research Engineer*
Structures Research Laboratory, Lockheed Aircraft Corporation

General design factors and considerations that govern the proportioning of tubular and cylindrical parts for assembly by flash welding are here enumerated and illustrated. A nomographic chart is included which gives the allowance for loss of length resulting from burn off and upset when flash welding various sizes of tubing. Tension test data are also given for flash welded joints in X-4130 steel.

FLASH WELDING is a process of resistance butt welding wherein the welding heat is developed by the passage of current in the form of a series of small arcs across a short gap between the surfaces to be welded, these surfaces being kept slightly separated until they have flashed off parallel and have reached the desired temperature. The upsetting action then takes place. The name "flash" arises from the fact that during the heating period oxidized metal is thrown off in a shower of sparks. The metal that is upset during the welding process appears as a ridge around the joint, called the flash.

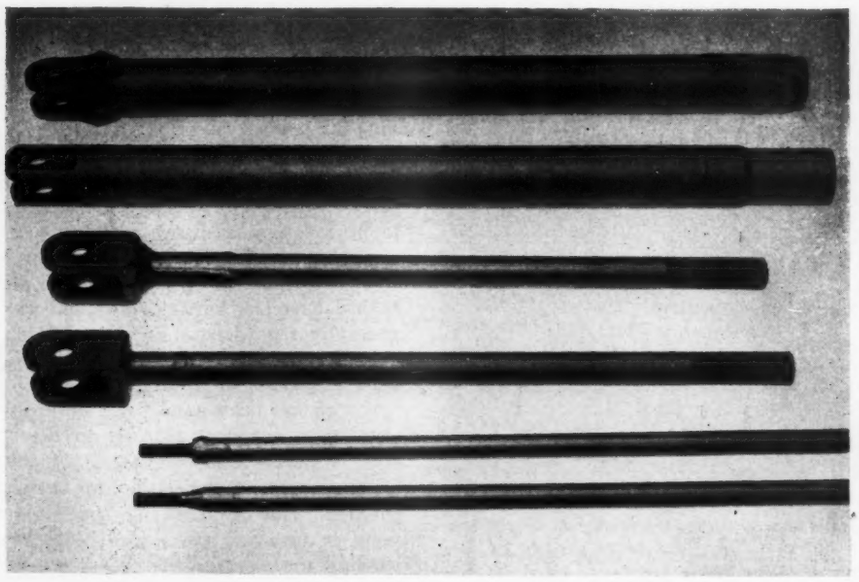
Advantages of flash welding are: Saving in production time, saving in cost per part, saving in weight, close tolerances (eliminates warping), 100 percent joint efficiency, mechanical repetition of welds, part can be finish machined prior to flash welding, neat appearance, does not require highly skilled labor (relieves grade A welders for other arc welding jobs that cannot be flash welded), preliminary indications are that parts previously heat-treated to 150,000–170,000 lb. per sq.in. can be welded and that considerable strength can be developed with no heat-treatment after welding.

While butt flash welding has been in common use in the automotive and other industries, in the aircraft industry the acceptance of flash welding has been slow because of the behavior of the chromium-molybdenum (X-4130) steel used so widely in that industry. Unless special care is taken to prevent air-hardening, the region affected by the weld heat is likely to become brittle.

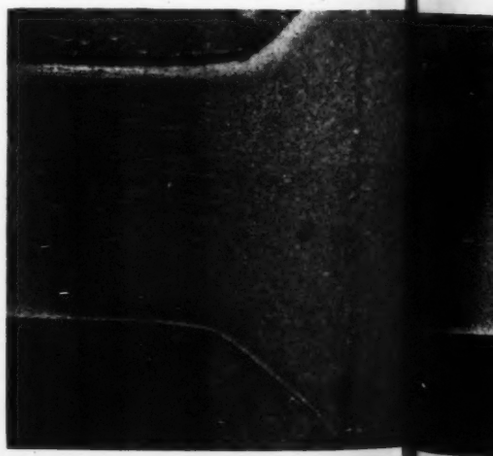
Investigations on the flash welding process indicate that it is a satisfactory means of fabricating X-4130 steel tubular structure, when certain factors are carefully controlled. Some of these factors are: Machine settings must be made accurately; proper dies, in good condition, must be used and accurately aligned; hydraulic system of the welding machine should be kept clear of air and any obstruction; as with other types of a.c. resistance welders, the power supply should be adequate to minimize undesirable voltage drops; and since the time interval between current cut-off and the start of upset is critical the established settings must be closely followed.

General Design

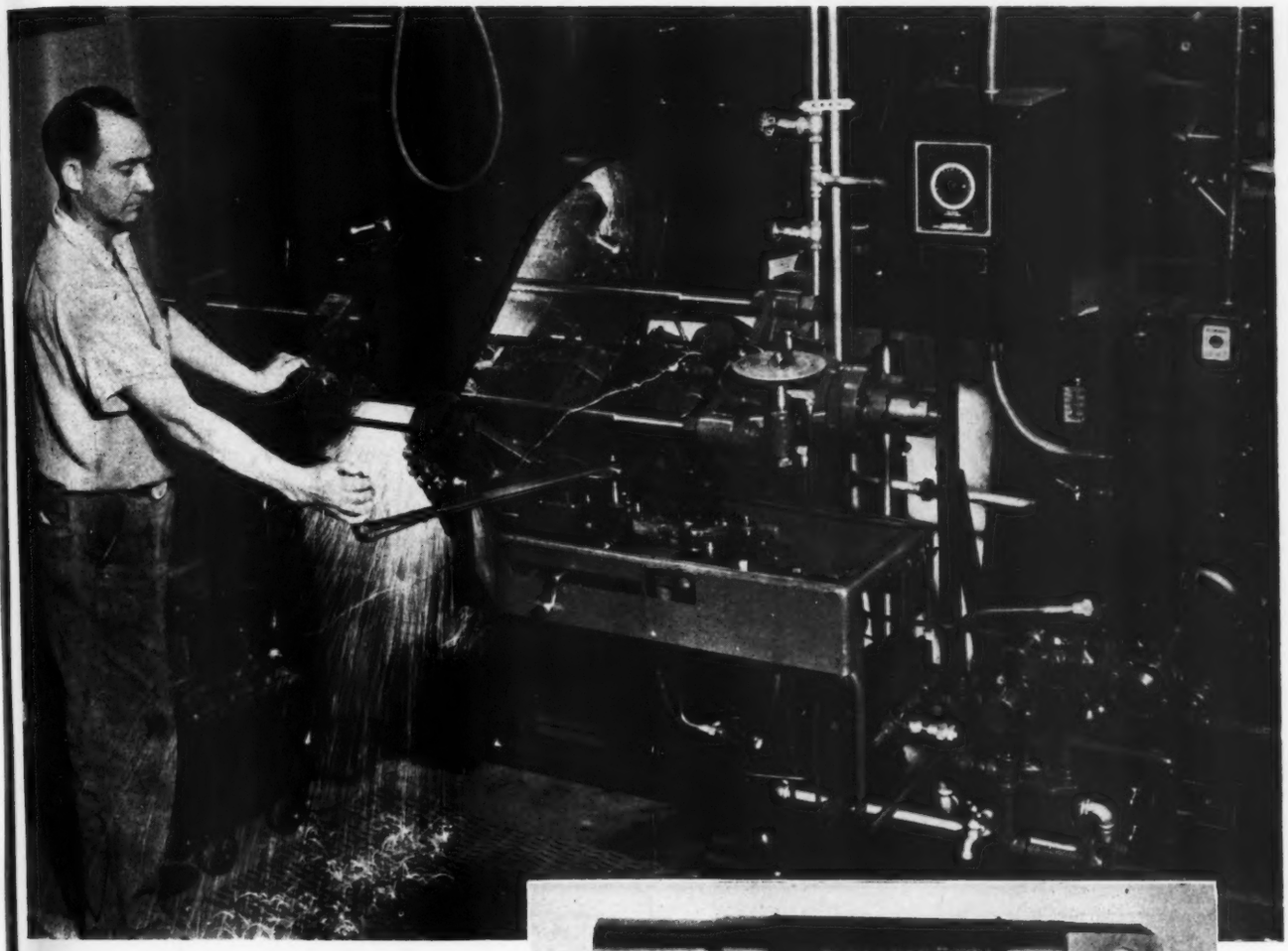
CADMIUM PLATED PARTS. Steel parts which are to be flash-welded should not be cadmium plated before welding, be-

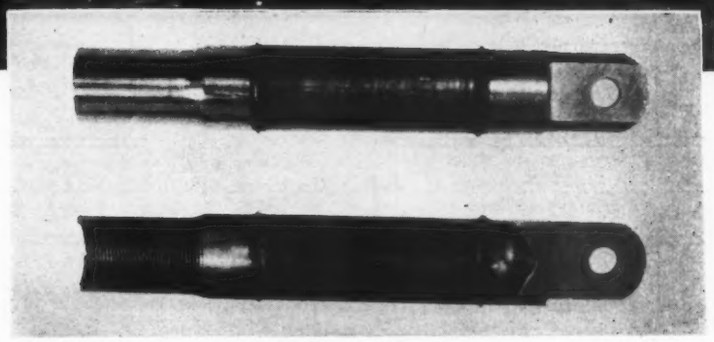


Typical examples of flash welded parts as compared to arc welded parts

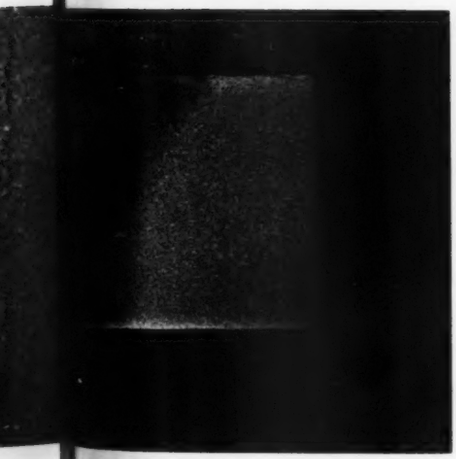


Flash welding is unlike arc or torch weldin... that the weld is composed of metal from p... themselves, rather than from material adde...





(Above) Flash welder in operation. Parts to be welded are gripped in dies. After flashing, hot metal at the joint is upset by hydraulic cylinders. (Below) Appearance of interoir and external flash



...bead, the resulting structure resembles that ...forging rather than a casting. Macrophoto... are of section through typical flash welds

cause the cadmium plate that burns off during the process of welding is injurious to the operator's lungs.

GAGE OF MATERIAL. Welding areas of parts that are to be flash-welded should not differ by more than a 1.2 to 1.0 ratio.

LIMITATIONS OF TUBE DIAMETERS. The determining factor which controls the size of tubing permissible for flash-welding is the cross-sectional area of the tube. On a 100 kva. butt flash-welder, the maximum area weldable is about 0.8 sq.in. for X-4130 steel, with a maximum outside diameter of about 2½ in. Minimum tubing size that can be successfully welded is ½ in. O.D. x 0.035 in. wall thickness.

FACE NORMAL TO CENTER LINE. It is necessary that the welding face be normal to the longitudinal center line of the tube. It is not necessary, or even desirable, that the edges to be welded should have a smooth finish. Tubing can be sawed and welded in the "as-sawed" condition.

REMOVAL OF FLASH. Flash should be removed to within about $\frac{1}{64}$ in. of the surface of flash-welded members. This is necessary on only the outside surface of tubular members.

CHAMFER. To obtain best results with

Table I—Test Data on Welded Specimens, X-4130 Steel, Tubing to Tubing

Tube Size		Specimens tested	Load, lb., at failure			Ultimate stress in 1,000 lb.			Failed in	
O.D., in.	Wall, in.		Max.	Min.	Aver.	Max.	Min.	Aver.	Tubing	Weld
3/8	0.035	5	4,780	3,600	4,300	128	96.4	115	5	0
1/2	0.035	25	6,720	6,150	6,409	131	120	125	24	1
3/4	0.156	25	32,800	32,000	32,252	113	110	111	25	0
1	0.049	25	17,200	16,100	16,736	117	109	114	23	2
1 1/4	0.065	25	29,000	25,500	26,808	120	105	111	25	0
1 3/8	0.083	25	44,700	34,100	39,076	133	101	116	19	6
1 1/2	0.049	20	27,600	26,300	26,930	124	118	121	18	2
1 1/2	0.065	25	32,800	30,600	32,320	111	104	109	22	3
2 1/8	0.083	25	64,700	53,200	60,648	121	99.5	113	15	10

wall thicknesses greater than 0.049 in. it is recommended that a bevel of 45 deg. be cut at the contacting surfaces of the parts. As shown on the nomogram Chart–I this chamfer is needed on one side only.

BURN OFF. Burn off is primarily a function of the wall thickness. Burn off includes upset and flash, or the total loss of metal per piece by flash welding. Chart I indicates burn off for various sizes of tubing.

ALLOWANCE FOR GRIP OF DIES. Sufficient area for the dies to grasp the parts must be provided. This is not only to insure good gripping, but also to provide sufficient area to carry the electrical current required for welding.

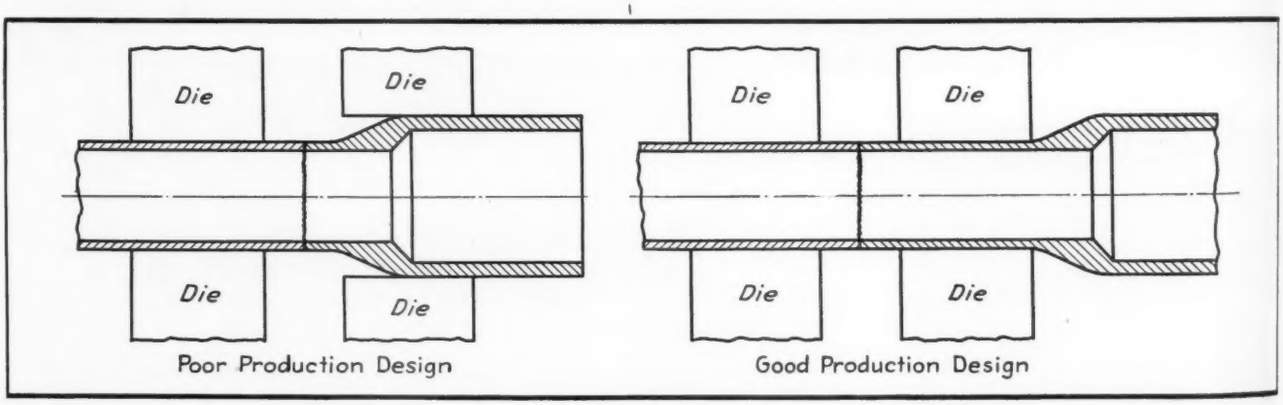
When designing a part to be flash-welded, if possible the outside diameter of the tube should be constant from the far end of the gripping die to the center of the flash-welded joint.

TENSION WELDS. Arc welds in tension are regarded unfavorably by designers and airworthiness authorities, but in flash-welded structures it appears permissible to assume the allowable stress to be 100 percent of the strength of the material. In designs where one tube is flash-welded to another of smaller cross-sectional area the allowable stress is computed on the strength of the smaller tube.

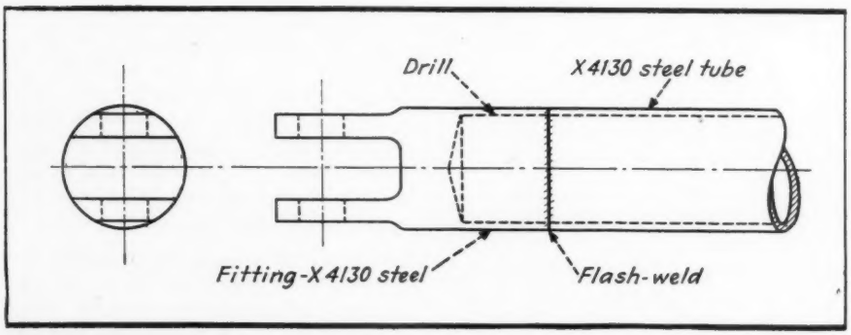
HEAT-TREATMENT. When parts are to be heat-treated after welding, such heat-treat should be done after the external flash has been removed.

Test Results

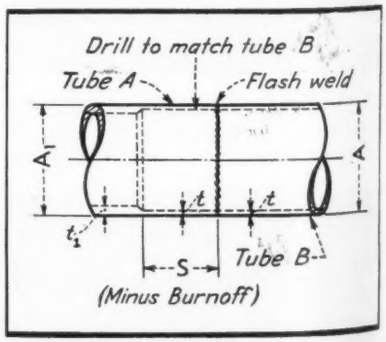
In Table I are listed some test data on flash welded tube parts. Before testing the flash was ground off on the outside of the tubing to within 64ths in. of the tubing surface, but left intact on the inside. The welds for these consistency runs were tested in the "as-welded" condition with no heat-treatment after welding. Static tension and tensile impact tests have shown that welds normalized after welding do not develop higher strength characteristics than welds made in normalized tubing and tested in the "as welded" condition.



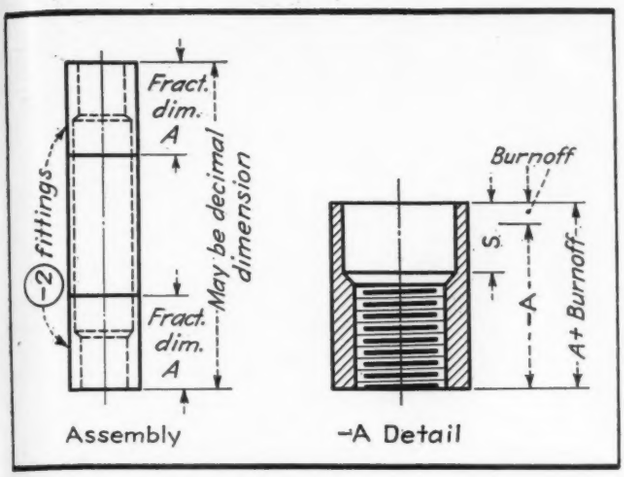
Symmetrical die sets. In order to insure proper heat balance and perfect alignment it is desirable to have the parts designed to fit symmetrical die sets.



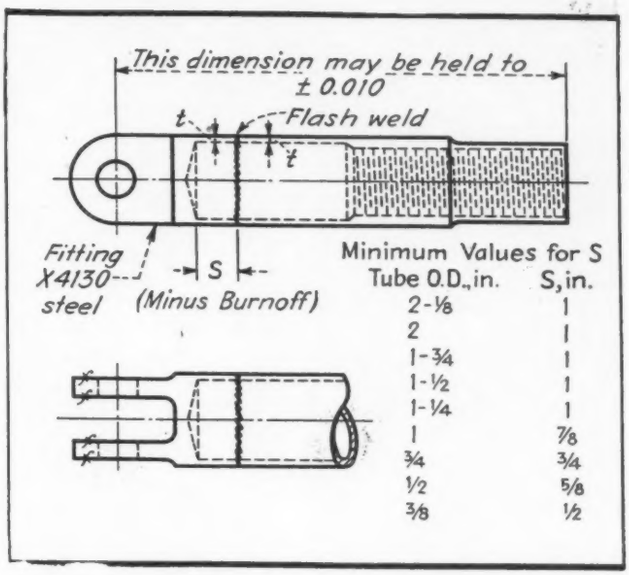
End fitting and tube assembly. When flash welding a fitting to a tube, the O.D. of the fitting should match the O.D. of the attaching tube.



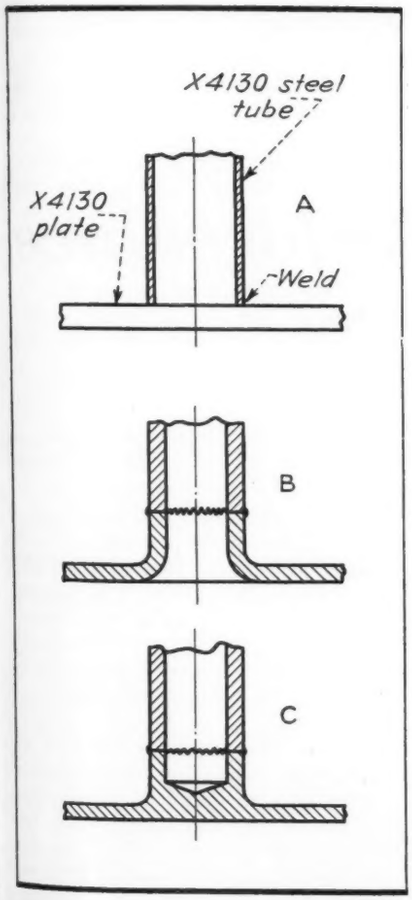
Match thicknesses. Bore the larger to agree with smaller in wall thickness.



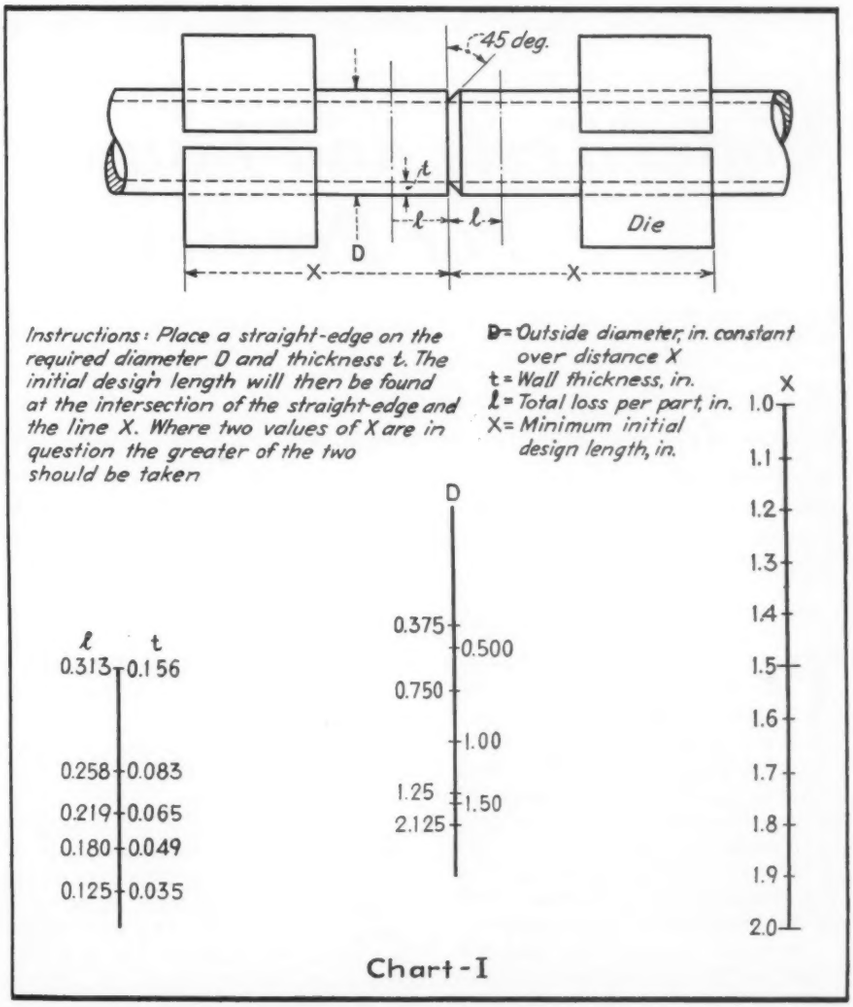
Assembly drawing notation. When detail parts are fabricated directly from information shown on assembly drawings it is suggested that the parts be individually designated as "Dash Numbers," and subsequently detailed in a manner that would enable the shop when making the part to allow for the dimension lost in the process of flash-welding because of material upset and burn-off.



Machining before welding. When two fittings such as are shown here are to be flash-welded it is possible to finish machine the parts before welding.



Welding tubing to flat stock. (A) Tubing cannot be flash welded to unprepared plate or sheet stock. (B) and (C) Tubing, if necessary, can be flash welded to flat stock if the plate is prepared in either of the ways shown.



Nomogram for determining the length of burn-off and for gripping X-4130 steel tube parts that are to be flash-welded.

Press Association, Inc., Photo

Installing a test model of a P-51 Mustang fighter in the throat of a wind tunnel

Model Tests and Laws For Predicting Performance

H. O. FUCHS

General Motors Corporation

A survey of the field of usefulness of models as a means for ascertaining the probable performance and behavior of new engineering developments. The author tells how to translate the measurements made on both similar and dissimilar models into their meaning for the real machine by the use of proper scale factors.

THE MOST certain way to find out how a new engineering development will work is to build it and try it out.

The cheapest way to investigate a project is usually a paper study, working with abstract symbols. But often the relationship between various features is such that it cannot be expressed by a formula or by an equation which can be solved without great labor.

Somewhere between the two extremes is the field of usefulness of models. This method also requires the use of imagination and judgment and of course, has limitations, but it can be a great saver of time and effort. Sometimes it is the only method to produce results.

Models can be grouped in three classes, different in their purpose and in their requirements:

1. Mockups are used to investigate the arrangement of component parts, to guard against interferences, and to arrange operating controls conveniently. They require usually little mechanism and no special attention is paid to materials and finishes. Often they are full scale. Geometric similarity or exact reproduction of exterior shapes is the only essential requirement.

2. Demonstration models can be invaluable in selling the idea of a new development or a new product. The old Chinese proverb might well be rephrased to say: "One picture is worth a thousand words and one model a thousand blueprints." These models must operate in a manner similar to the real product. In addition, their exterior shape should also be similar; an attractive finish helps as much as does a salesman's neat appearance.

3. Investigation models are used in development work to measure the effect of conditions such as load, speed, friction and so on. The requirements for these models depend entirely on the question to which they shall furnish an answer. The appearance of investigation models does not matter at all.

Where the flow of fluids, of stresses, or of heat is studied, the shape of the surfaces is of major importance. In these fields, models must be geometrically similar to the full scale bodies

and the classic model laws must be applied. In static or dynamic problems, however, shape does not matter. The models may look very different from the machines they represent. The rules which must be followed in these cases permit more liberty in the choice of scales than the classic model laws. For brevity this type of models shall be referred to as dissimilar models.

As a rule nothing is saved by using the same model for more than one purpose. By splitting up the problem into several questions and investigating each separately the models become simpler, more convenient to operate and cheaper to make.

The part of this article which follows shall be concerned only with models in the third group above, those used for experimental development work, and only with mechanical models.

Model Laws

In all model experiments it is necessary to translate the measurements made on the model into their meaning for the real machine by the use of scale factors. The choice of scale factors is sometimes entirely arbitrary; in other instances the various scale factors must satisfy certain relations; in exceptional cases it may happen that the relations which must be satisfied admit of only one set of scale factors, all in a 1 to 1 ratio, in the event of which model experiments are impossible.

The relations between scale factors depend entirely on the types of forces involved in the operation of the machine part. It is therefore important to have a clear idea of their general relationship before building the model.

The general model laws given in handbooks usually assume geometric similarity between model and real machine. As previously mentioned and as shall be seen later, geometric similarity is often not necessary and considerable freedom from the classic model laws can be obtained. A similar example will serve to show what these model laws mean.

Assume that the project is to investigate the performance of a small spring loaded valve which is operated by a uniformly rotating crank through a space linkage which cannot be represented in one plane. A model is built on an enlarged scale of 4 to 1. What model laws must be considered?

Let values which are measured on the real valve or apply to it be represented by capital letters; values of the model by lower case letters, and the scale factors by greek letters. The enlarged scale is then represented by the statement

Scale of lengths $= l/L = \lambda = 4$

CASE A—*Forces are not considered.*

The successive positions of the valve can be plotted over the crank angle and from this plot velocities and accelerations can be derived. To introduce the model laws, assume that speedometers and accelerometers had been attached on the model valve and their readings plotted over the crank angle. To take readings without haste the valve is operated slowly. 200 sec. of model operation correspond to 1 sec. running time of the actual machine. So that

Scale of times $= t/T = \tau = 200$

$$\text{Scale of velocities} = v/V = \frac{(l_1 - l_2)/t}{(L_1 - L_2)/T} = \lambda/\tau = 1/50$$

and similarly

$$\text{Scale of accelerations} = a/A = \frac{(v_1 - v_2)/t}{(V_1 - V_2/T} = \lambda/\tau^2 = 1/10{,}000$$

Once the scales [λ, φ, τ.] of the fundamental quantities (length, force, time) are chosen, the scales of the derived quantities (velocity, acceleration, moment of inertia) are obtained in the same manner as the dimensions of the derived quantities from the fundamental dimensions (inch, pound, second).

For this model test the weight of the parts and the force of the spring did not matter. Neither did the cross-section of the links, which need not have been geometrically similar to those of the real linkage.

CASE B — *Spring force necessary to keep the valve in contact with its tappet is in question. Valve is horizontal. Friction and gravity can be neglected.*

At corresponding points, the forces of the real spring and of the model spring are F and f respectively, so that

Scale of forces $= f/F = \varphi$

The mass of the real valve is M and the mass of the model valve is m giving

Scale of masses $= m/M = \mu$

At some point in the operation of the real valve and at some speed of rotation the valve will begin to chatter or jump where F equals MA. At the corresponding point and the corresponding speed of the model valve it is desired to obtain f equals ma or

$\varphi F = \mu M \frac{\lambda}{\tau^2} A$ and since F equals MA

$\varphi = \mu\lambda/\tau^2$

This means that of the four scale factors three can be arbitrarily chosen. The fourth is then determined.

If model and real valve are geometrically similar but made of different materials whose densities are in the ratio d/D equals δ, then μ equals $\delta\ \lambda^3$ and the model law becomes for geometrically similar models

$$\varphi = \delta\ \lambda^4/\tau^2$$

This is known as Newton's model law. It applies whenever inertia forces only need to be considered. It is apparent, therefore, that disregard of geometric similarity will facilitate the job, because it is easier to load the model valve and obtain a desired μ than to choose a material with a suitable δ ratio.

CASE C—*Valve is assumed to be arranged vertically, so that gravity also enters the problem.*

Corresponding spring forces must now be in the same ratio as corresponding weights or masses and in addition to Newton's model law it is necessary to satisfy the condition

$$f/F = \varphi = m/M = \mu$$

or for geometrically similar models

$$\varphi = \delta\ \lambda^3$$

From the two equations for the scale factors

$\varphi = \mu$ $\qquad$ $\varphi = \mu\lambda/\tau^2$

As in Case *B* it follows that

$1 = \lambda/\tau^2$ $\qquad$ $\tau^2 = \lambda$

Of the four scale factors only two can be arbitrarily chosen, either λ or τ and either φ or μ. The other two are then determined.

This law is named after Froude. It must be used whenever inertia and gravity forces enter the problem. Tests on the waves set up by ship models are one of its most frequent applications. For these tests the law is usually given in the form:

$$v^2/l = V^2/L$$

which follows directly from $v/V = \lambda/\tau$ Therefore at 4 times full size the r.p.m. of the model crank are ½ of the corresponding R.P.M. of the real machine, which will give the model valve twice the linear velocity of the real valve.

CASE D—*Valve spring itself and its surges are considered.*

At the surge frequency the elastic forces just balance the inertia forces. If the model spring is made of the same material as the real spring to scale at 4 times size, its rate will be 4 times the rate of the real spring and at corresponding deflections the elastic forces of the model spring will be λ^2 or 16 times the elastic forces of the real spring. The ratio of the masses of corresponding parts will be 64 to 1. The ratio of the accelerations will be λ/τ^2 to $4/\tau^2$ so that inertia forces are in the ratio λ^4/τ^2. To keep the same ratio between both types of forces at corresponding speeds the following conditions must exist

Scale of spring forces = Scale of inertia forces

$\lambda^2 = \lambda^4/\tau^2$ $\qquad$ $\tau^2 = \lambda^2$ $\qquad$ $\tau = \lambda$

In this case, 1 cycle per sec. of the 4

times size model corresponds to 4 cycles per sec. of the real spring. The surge frequency of the model spring is ¼ of the surge frequency of the real spring.

The relation that "resonance frequencies decrease at the same rate at which size increases for geometrically similar structures" is one of the reasons why large structures cannot be designed simply as enlargements of smaller types.

If the model spring is made of material with different density and shear modulus and the ratio of the moduli is g/G equals γ, then from

$$\varphi = \tfrac{1}{4}\gamma\,\lambda^2 \text{ and } \varphi = \delta\,\lambda^4/\tau^2$$

is obtained the relation

$$\tau^2 = \lambda^2\,\delta/\gamma$$

This is Cauchy's model law for geometrically similar structures in which inertia forces and elastic forces act jointly. Cauchy's law is sometimes written:

$$v^2 d/e = V^2\,D/E$$

where d and D are densities; and e and E are moduli of elasticity.

If different materials are used for model and real machine, the ratio E/G or Poisson's ratio should be the same for both. This condition is sometimes hard to fulfill and usually not of great importance.

CASE E—*Inertia, gravity and elastic forces jointly appear in the operation of the machine. The relations of both Case C and Case D must be fulfilled.*

From Case C, $\lambda = \tau^2$

From Case D, $\lambda = \tau$

The only possible solution is λ equals τ equals 1 which means a full scale model. This case therefore excludes the use of models.

CASE F—*Viscous damping and inertia are involved.*

Considerations exactly like those given lead to Reynold's model law $\tau = \lambda^2\delta/\alpha$ where α is the ratio or scale of absolute viscosities; or

$$v\,l/k = VL/K = \text{Reynolds' number,}$$

where k and K are kinematic viscosities.

This law applies to the flow of fluids in pipes or to airplanes and submerged coats, but not to flow with free surface where gravity can act.

The difference between Froude's and Reynolds' law, and the difficulty of satisfying both, should be noted. (See Prantl and Tietjens, Applied Hydrodynamics, p. 10.)

Dissimilar Models

The model laws which were considered above can be applied if the type of forces which act are known. Their classic forms (Newton, Cauchy, Froude, Reynolds) are based on geometric similarity between model and real machine.

In problems like the flow of fluids where the shape of the surface is of major importance, these model laws must be strictly complied with. In problems of dynamics, on the other hand, the shape of the masses does not matter. A rigid mass of any shape can be replaced by another one with the same center of gravity and moments of inertia. An infinite choice of such equivalent replacing masses is always available, so that certain other arbitrary conditions can be fulfilled, which may define the desired shape of the replacing mass—for instance cylindrical, or composed of a number of rigidly connected point masses. Springs also may be replaced in such a manner without regard to geometric similarity; in some cases it may be convenient to replace springs by pendulum suspensions of the correct frequency.

The model shown in Fig. 1 was used in investigating the behavior of automobile rear axles. The axle was replaced by a rod, the combined effect of tires and springs by a short pendulum; the effect of springs alone—after the tires have left the ground—by a long pendulum; the time scale was made sufficiently large so that the "bumps" could be produced by hand. This simple model gave a complete explanation of the apparently unreasonable preference of axles for one mode of vibration over another.

Models which are much simpler than exact geometric scale reproductions can be obtained by short cuts of this type whenever the elements of the machine can be considered as pure masses, pure elasticities, or pure dampers. In the case of the axle the elasticity of the axle itself could be neglected in comparison with the elasticity of springs and tires, and the mass of the springs could be neglected in comparison with the mass of the axle.

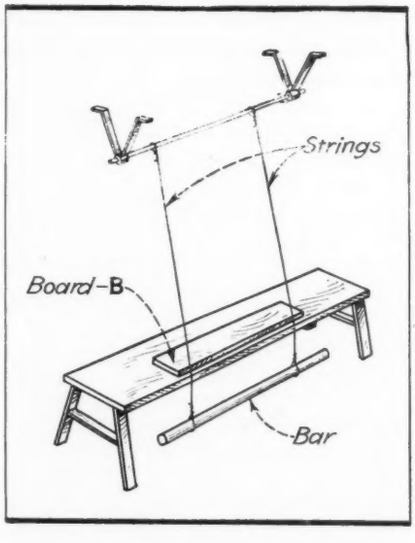


Fig. 1—A dissimilar model. A bar suspended by strings represents an axle. Board B is used to apply bumps by hand

In models with such pure masses, elasticities and resistances (or lumped parameters), the laws reduce to

1. Periods of oscillation will vary as the square root of static deflections.

2. At corresponding velocities, damping forces on the model must be the same fraction of critical damping as on the real machine.

3. If more than one degree of freedom appears, the ratios of the periods of the various natural modes must be maintained.

These rules admit of much more liberty than the classic model laws. For instance, the joint effect of inertia, gravity and viscosity cannot be represented on a geometrically similar model; but on the model of a car where the axles and body may be considered as pure masses, the springs and tires as pure elasticities and the shock absorbers as pure dampers, the elements of the model can be arranged so that each one gives the same scale of forces. When damping is less than 1/10 critical, it can usually be neglected entirely.

A very complete analysis by means of a dissimilar model has recently been published (C. A. Meyer and H. B. Saldin. Model Tests of Two Types of Vibration Dampers. *Jour. of Applied Mechanics*, Vol. 9, No. 2, pp. A59 to A64, June 1942.) with a discussion of how the scales were obtained.

A further convenience can often be obtained by deliberately distorting the scales. In drawing the profile of a road it is customary to show the elevations at a much larger scale than the distances. In model tests on the deflection of structures it will usually be permissible to choose a reduced scale for the structure itself, but an enlarged scale for its deflections more plainly visible and easier to measure. The same applies to strain tests with rubber models. The use of model tests in the analysis of structures has been described in several publications. (O. Gottschalk, Correct Design of Rigid Structures. *Jour. of the Franklin Institute*, Vol. 232, No. 6, p. 553-578, Dec. 1941.)

As long as deflections are proportional to loads (transverse loads only), the choice of scales is quite arbitrary. If beam columns or toggle effects must be considered, the deflections will no longer be simply proportional to the loads. In these cases, the ratio of applied loads to critical buckling loads

Table I—Summary of Model Rules

Scale ÷ 1 = Quantity measured on model ÷ corresponding full size quantity.
Symbols for scales: α, viscosities; δ densities; ϵ, γ moduli of elasticity, shear; λ lengths; φ forces; τ times; μ masses.
The scale of any quantity is obtained from the fundamental scales [λ, φ, τ] as the dimension from the fundamental dimensions [in., lb., sec.]. Example. scale of accelerations = λ/τ^2.

FOR GEOMETRICALLY SIMILAR MODELS

Force scales for different types of forces	Additional relations if two types of forces act together.			
	Types of Forces	Relation	Named After	Where Used
Inertia $\varphi = \delta\lambda^4/\tau^2$	inertia + gravity	$\tau^2 = \lambda$	Froude	Flow with free surface; boats, channels.
Gravity $\varphi = \delta\lambda^3$	inertia + elasticity	$\tau^2 = \lambda^2\delta/\epsilon$	Cauchy	Surges; vibrations, buckling
Elastic $\varphi = \epsilon\lambda^2$	inertia + viscosity	$\tau = \lambda^2\delta/\alpha$	Reynolds	Flow without free surface. Pipes, Planes ,Torpedoes
Viscous $\varphi = \alpha\lambda^2/\tau$	gravity + elasticity	$\lambda = \epsilon/\delta$		Heavy structures (little used)

FOR DISSIMILAR MECHANICAL MODELS

a. Parts may be loaded and $\lambda^3\delta$ replaced by μ in above laws.
b. Parts may be made to different scales to give the same φ.
c. Parts may be replaced by dynamic or kinematic equivalents.
d. Scales may be distorted.
(1) Time scale will equal ratio of square roots of static deflections (model ÷ full size).
(2) If several degrees of freedom are present: the ratios of their frequencies must be kept.
(3) If damping counts: it must be the same fraction of critical at corresponding velocities.
(4) If deflections are not proportional to loads: the ratio of applied loads to critical loads must be kept.

must be the same on model and real structure. If this condition is fulfilled, very flexible model structures with large deflections can be used and will often lead to a clearer conception of the problem than a purely mathematical analysis.

Several references have been given by R. J. Roark ("Formulas for Stress and Strain") for the use of models made of plaster or paper for the determination of permissible load. In problems concerning the strains in complicated parts subjected to bending and twisting, or the effect of stress raisers and stress reliefs, models made of soft rubber will often give a quick hint of conditions which would never have been suspected on the basis of a purely mathematical study.

Analogs

A further step away from geometric similarity is often taken in cases where analysis of the problem leads to a differential equation which may be written down but cannot be solved; frequently it is possible to find another physical process which leads to the same differential equation and permits more direct measurements. The easily measured physical process is then set up and serves as an analog for the process on which measurements cannot be taken.

Prandtl's experimental solution of torsion stress distribution probably is the best known analog. The torsion stresses are found by measurements of the deformation of membrane "windows" subjected to internal pressure. The stresses at any point are proportional to the slope of the corresponding point of the membrane and the conversion factor is given by the proportionality between the volume contained under the bulge of the membrane and the torsion applied to the stressed section.

A similar analog has been developed by A. Nadai (Plasticity), for torsion stresses beyond the yield point, which has recently been extended to hollow sections, by M. A. Sadowsky, (An Extension of the Sandheap Analogy for Plastic Torsion, *Jour. of Appl. Mech.* Vol. 8, No. 4, p. A166, Dec. 1941). Electrical and hydrodynamic analogs for stress problems have also been used.

Differential analyzers on which the conditions of the problem are set up as cams and the result traced as a curve are analogs which are almost as abstract as a purely mathematical study. A relatively simple analyzer, which was used as model of an automobile suspension, has been described by R. Schilling and H. O. Fuchs (Modern Passenger Car Ride Characteristics, *Jour. of Appl. Mech.*, Vol. 8, No. 2, p. A59, June, 1941).

Incidental Advantages of Models

The operation and study of models often results in advantages other than a convenient and low cost solution of a particular problem.

A single test on a model can often be used as a representation of a number of operating conditions. One test on the dissimilar model of an axle shown in Fig. 1 can for instance be interpreted as representing fast bumps on a stiffly sprung car or slow bumps or a softly sprung car, and in turn slow bumps might mean low speed over short waves or high speed over long waves. As long as the ratio bump frequency to natural frequency of the axle is kept the same, any of these interpretations is correct.

It should be noted that the ratio which must be kept is a ratio of two quantities with the same dimension and therefore dimensionless. Plotting out data in terms of such dimensionless ratios converts almost any test into a model test which can be interpreted in many different ways by choosing appropriate scales for the conversion from model to full size. Dimensionless plotting is slightly harder to read than ordinary graphs plotted over dimensioned scales, but it condenses a great deal of information into one single line or even one single point. Reynolds' original work is a classic example of such condensation. (See Prandtl & Tietjens, "Applied Hydrodynamics," p. 31.) Dimensionless charts are becoming more and more frequent in modern engineering literature.

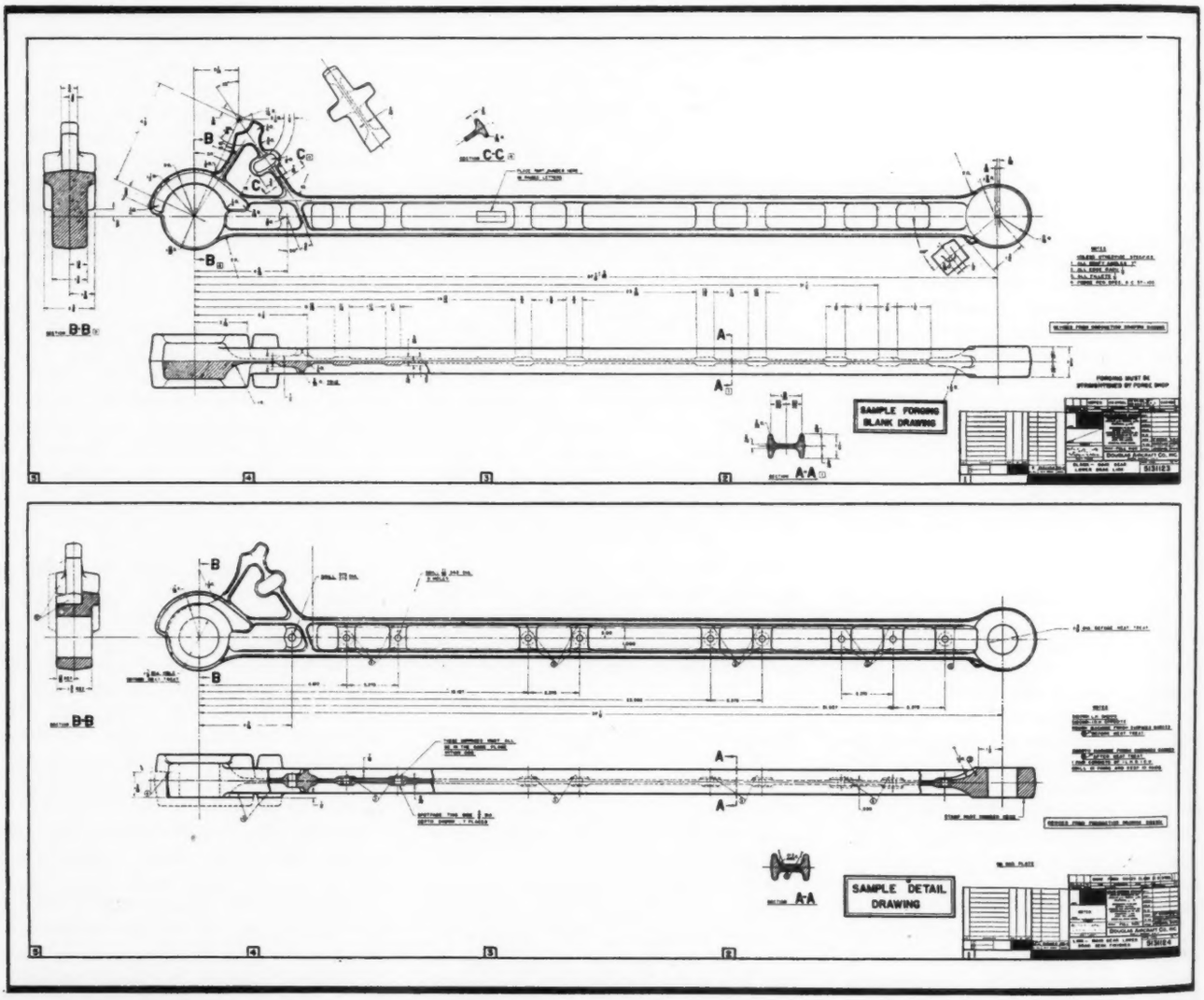
By means of model laws or by dimensional analysis a test made on one particular machine can also be used to predict the performance of similar machines of different size which may be projected. While model laws are not necessary for making such estimates, they do offer a definite and quick method of analysis.

Finally, the operation and study of models can give a clearer insight into the fundamental laws which govern the performance of a machine than either full scale tests or purely theoretical analysis can give. This results from the convincing manner in which models often point out conditions which might have been overlooked completely in a "paper" analysis, from boiling down a machine to its essentials in the design of the model and from the possibility to apply extreme conditions which cannot be duplicated on the real machine.

Design of Forgings For Speedier Production – II

O. A. WHEELON
Methods Analysis Engineer, Douglas Aircraft Company, Inc.

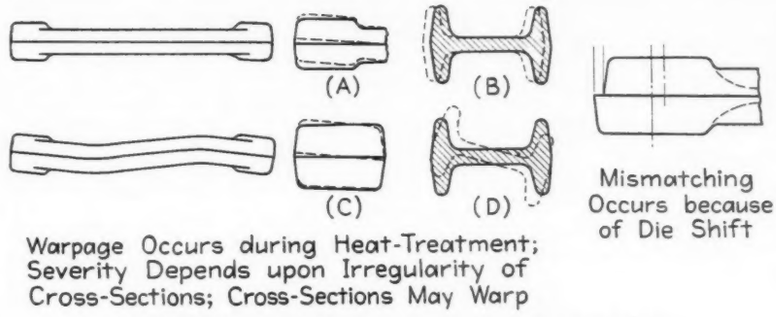
WARTIME OBJECTIVES of forging design must meet the need for speedier production of forgings and longer forging die life in order to relieve overworked forging presses and die sinking capacity. They can be achieved by keeping draft angles, fillets, edge radii, thin webs and tolerances as large as practicable, and by correctly specifying these details on forging drawings. Part I of this article (*P. E. September 1942, p. 524-529*) showed the reasons why these details are necessary and gave recommendations for correct proportioning and computation of forging dimensions. Part II shows, in the same handbook style, recommendations for tolerances, how to compute allowances and how to make forging drawings. See also this month's Reference Book Sheets.



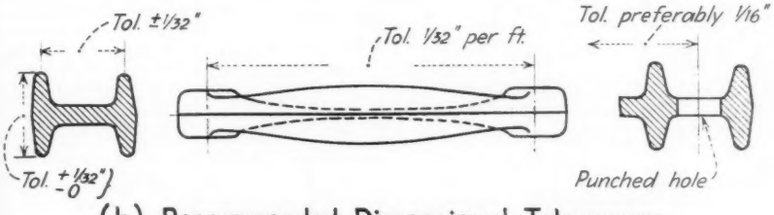
Sample forging blank and machining drawing by the Douglas Aircraft Company embody correct forging design, and illustrate proper methods for making forging drawings and adding notes. General information may be given on the forging drawings by a notation such as the following:

NOTE: Unless otherwise specified.
All draft angles 7 deg.
All fillet radii 3/8 in.
All corner radii 1/8 in.

The kind of metal and its specifications must be given. Heat-treatment and specifications must be given on drawings for steel forgings. Details of dimensioning are covered in illustrations on the following pages.



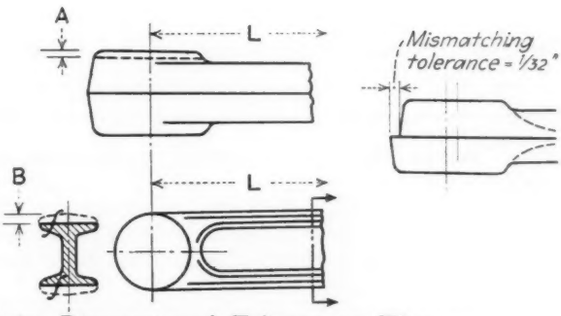
(a) Effects of Warpage and Mismatching



(b) Recommended Dimensional Tolerances

L	A
Up to 10	0
10 to 20	1/32
20 and up	1/16

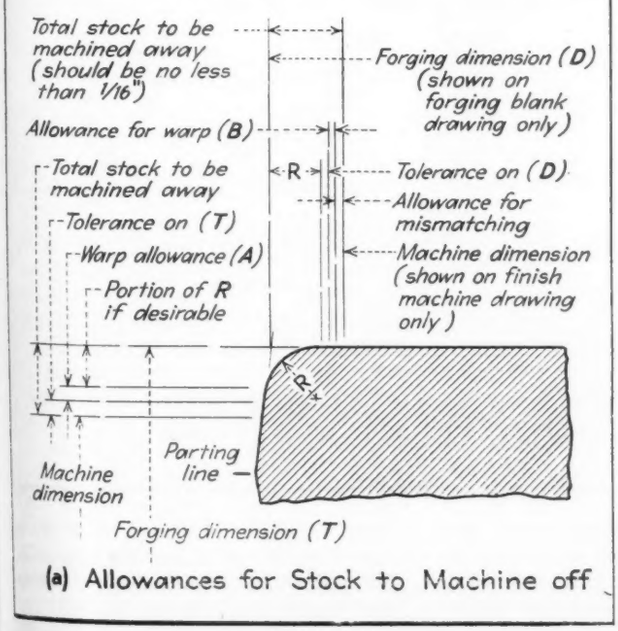
L	B
Up to 10	0
10 to 20	1/16
20 and up	1/8



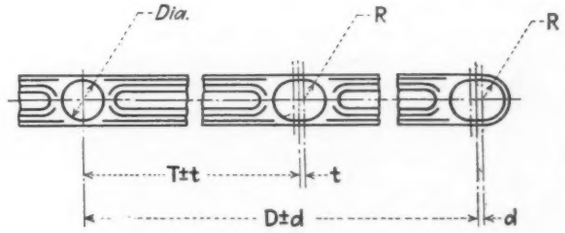
(c) Add to Dimensional Tolerances These for Warpage and Mismatching

Dimensional tolerances should be kept as large as the design will permit. The brief description of the forging process and sketch (*a*) at left give some idea of the difficulty of holding dimensions within close limits. Variations which must be accounted for are: (1) Shrinkage and warpage of the forging as it cools. (2) Mismatching of forging die. (3) Failure to bring the finish dies together. This results in a variation of thickness and other dimensions across the parting line. (4) Die wear, which causes dimensions to increase as the die is used. In commercial forging practice the impressions are machined to the lower limits of the drawing dimensions. When the impression has been worn to the upper limits the die must be resunk. Liberal tolerances provide greater die life by permitting greater die wear.

Recommendations for minimum dimensional tolerances are given in the illustration. Short dimensions within a die (width) can be held to plus or minus $\frac{1}{32}$ in. or less where required. Dimensions across the parting line (the thickness of the part) can be held to $+\frac{1}{32}$ in. —0.0 in. for small forgings under 10 sq. in. in projected area. Large forgings may require tolerances of $+\frac{1}{16}$ in. $-\frac{1}{32}$ in. Long dimensions (length) should be allowed to vary by $\pm\frac{1}{32}$ in. per ft. (0.003 in. per in.). Tolerances for the location of punched holes should be at least $\pm\frac{1}{32}$ in., preferably $\frac{1}{16}$ in. Tolerances for warpage of parts and mismatching of dies, shown in sketch (*C*) at left, must be added to the appropriate dimensions in addition to the above tolerances.

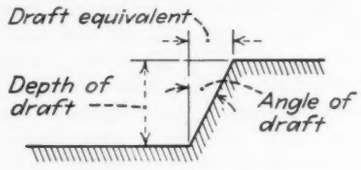

Total stock to be machined away (should be no less than 1/16")
Forging dimension (D) (shown on forging blank drawing only)
Allowance for warp (B)
Total stock to be machined away
R
Tolerance on (D)
Allowance for mismatching
Tolerance on (T)
Warp allowance (A)
Machine dimension (shown on finish machine drawing only)
Portion of R if desirable
R1
Machine dimension
Parting line
Forging dimension (T)

(a) Allowances for Stock to Machine off



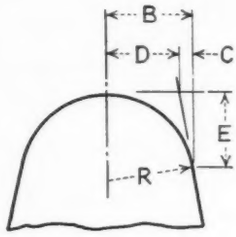
(b) Location of Bosses

Allowances for finish machining should include an amount to cover tolerances on the overall dimensions and an allowance for warpage and mismatching of dies. If the corner radius is to be machined away, this must also be added to the total forging dimensions as set in (*a*) left. For bosses set far apart (*b*) and which are subsequently to be bored out, it is recommended that one boss be made circular and the other boss or bosses be elongated by the forging length tolerance, even when portions of the end bosses must later be machined off. *(Continued on next page)*



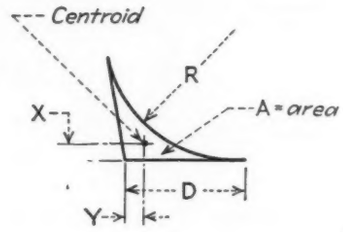
Depth in In.	Angle of Draft		
	5 deg.	7 deg.	10 deg.
1/8	0.0109	0.0153	0.0220
5/32	0.0137	0.0192	0.0276
3/16	0.0164	0.0230	0.0331
7/32	0.0192	0.0269	0.0386
1/4	0.0219	0.0307	0.0441
9/32	0.0246	0.0345	0.0496
5/16	0.0273	0.0384	0.0551
11/32	0.0301	0.0422	0.0606
3/8	0.0328	0.0460	0.0661
13/32	0.0355	0.0499	0.0716
7/16	0.0383	0.0537	0.0771
15/32	0.0410	0.0576	0.0827
1/2	0.0438	0.0614	0.0882
9/16	0.0492	0.0691	0.0992
5/8	0.0547	0.0767	0.1102
11/16	0.0601	0.0844	0.1212
3/4	0.0656	0.0921	0.1322
13/16	0.0711	0.0998	0.1433
7/8	0.0766	0.1074	0.1543
1	0.0875	0.1228	0.1763

Die-Draft Equivalents



Dimension	Angle of Draft		
	5 deg.	7 deg.	10 deg.
B	0.9962 R	0.9925 R	0.9848 R
C	0.0799 R	0.1078 R	0.1457 R
D	0.9163 R	0.8847 R	0.8391 R
E	0.9129 R	0.8781 R	0.8263 R

Round Top Flange Dimensions

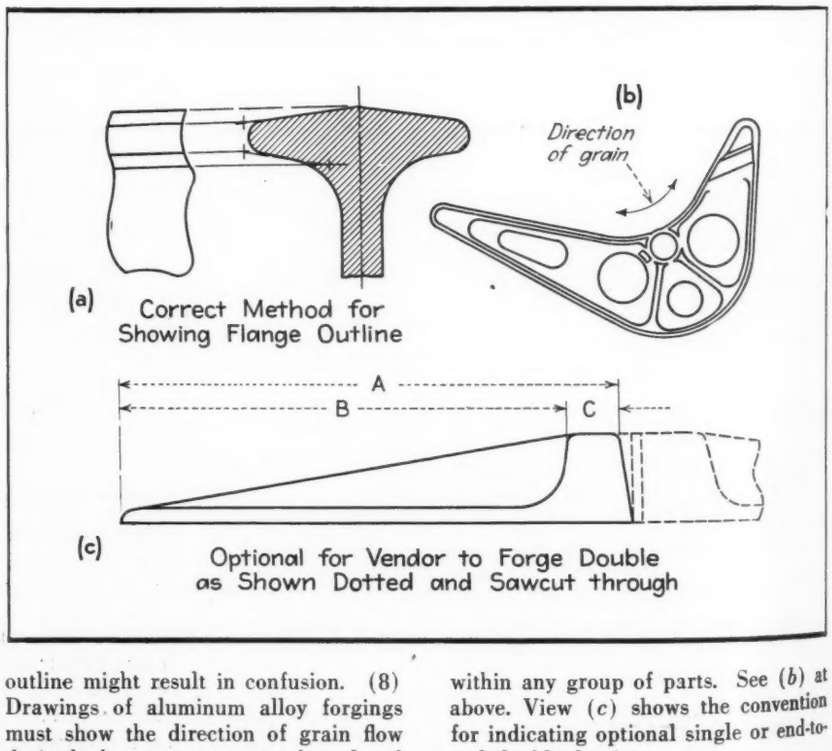


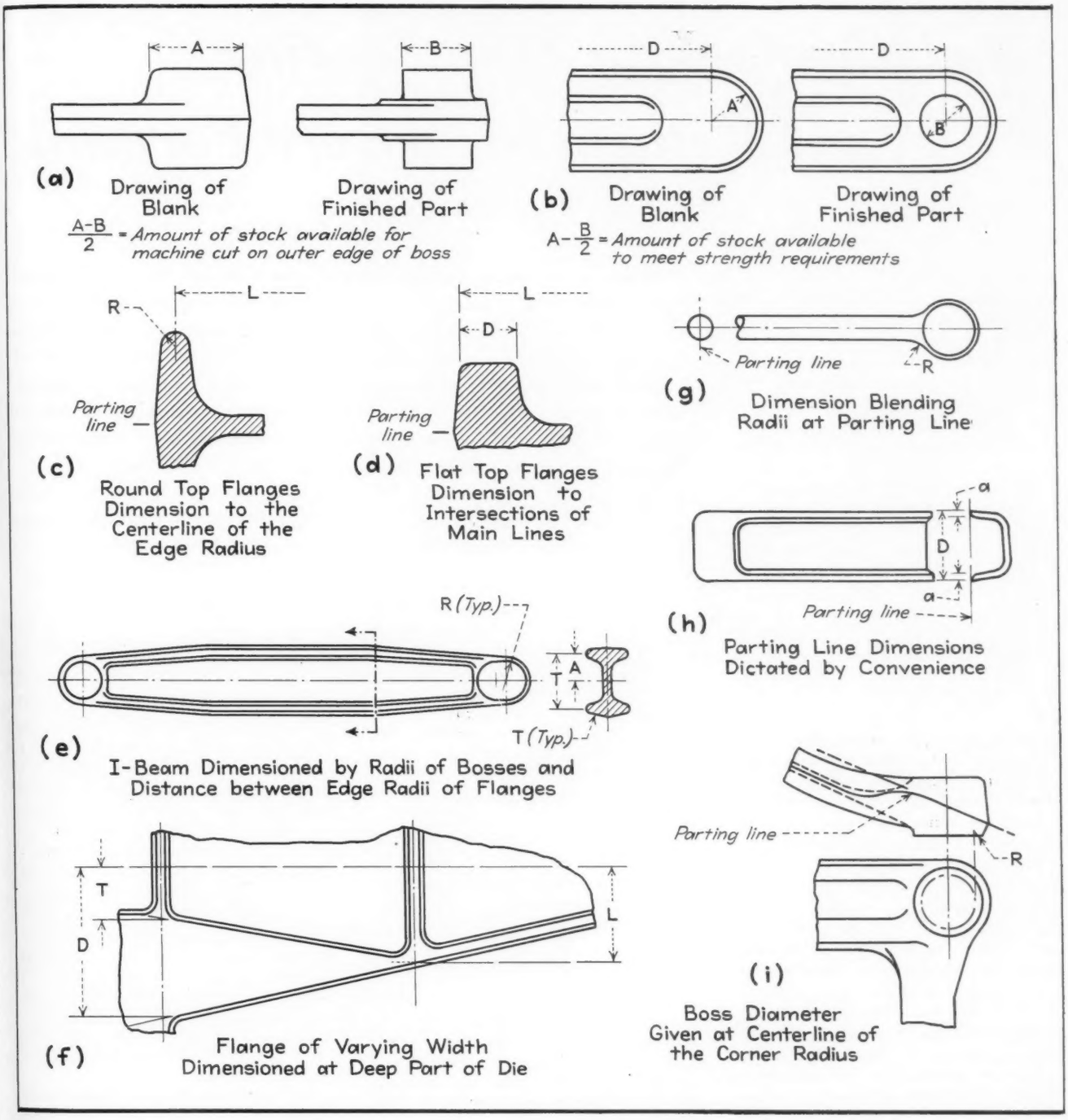
Dimension	Angle of Draft		
	5 deg.	7 deg.	10 deg.
A	0.1745 R^2	0.1604 R^2	0.1410 R^2
Y	0.1843 R	0.1705 R	0.1514 R
X	0.2011 R	0.1928 R	0.1804 R
D	0.9163 R	0.8847 R	0.8391 R

Fillet Dimensions

Section properties. The above physical properties of forging sections with draft angles of 5, 7 and 10 deg., although incomplete, are sufficiently accurate to be used for drafting detail, weight estimation, stress computations, determination of inertia, etc. For charts giving areas and moments of inertia for forging sections, see this month's Reference Book Sheets on pages 612 to 614.

Making drawings of forgings. The draftsman should use every effort to make his forging drawings clear, since forgings are often not easy to picture. However, a certain amount of dependence must be placed upon the die sinker's judgment. The following practices should be adhered to: (1) Drawings should be full size. (2) Separate drawings should always be made of a forging blank and the machine parts. (3) The parting line and forging plane should be shown and labeled. (4) Cross-sections help visualize a part and should be used freely. (5) In order to give the plan view more graphic depth, projected views should show lines representing the intersecting lines of the surfaces as illustrated in (*a*) at right. (6) Part numbers should be located by the designer in a region of low stress on a surface which will not be in contact with others, or will not later be machined off, and which is parallel to the forging plane. Raised letters should be specified. (7) In order that machine work may be seen at a glance, machining drawings should show in dotted outline that portion of the forging blank which is to be machined off, unless such outline might result in confusion. (8) Drawings of aluminum alloy forgings must show the direction of grain flow desired, but arrows must be placed within any group of parts. See (*b*) at above. View (*c*) shows the convention for indicating optional single or end-to-end double forgings.





Dimensioning forgings. Two important principles of dimensioning should be followed when laying out, detailing or checking forging drawings: (1) Dimension the part as it is desired. It is true that a certain saving in die cost can be realized by dimensioning the parts to facilitate die sinking. However, the dies are made but once, whereas the parts are made and checked against the drawing many times. (2) Dimension the forging blank so that it can be most easily checked against the machining drawing to ensure sufficient material for finished work or to meet strength requirements. This will save much time in engineering.

As an aid to inspection and detailing, dimensions should generally connect those points which lie deepest in the forging die. Methods shown in views (*c*), (*d*), (*e*) and (*f*) are based on this general rule. Some parts can be more easily dimensioned at the parting line than at the deep part of the die. Blending radii can be dimensioned only at the parting line, as shown in (*g*). View (*h*) illustrates a forging in which convenience dictated the dimensioning at the parting line. For circular bosses having faces which are not parallel to the forging plane, dimension the boss diameter at the center line of the corner radius, as shown in (*i*).

Where a forging is made to follow a mold line determined by a table of offsets from reference lines of the machine on which the forging is to be assembled, such as the fuselage frame of an airplane, the forging blank should be completely dimensioned in itself with offsets to reference lines drawn through from some defining point on the forging. All reference to other parts of the complete machine should be eliminated.

Steel Sheets With Zinc Coating That Withstands Severe Forming

Elimination of cracking and flaking of zinc coatings, long detrimental to the fabrication of galvanized sheet metal products, has been accomplished by the development of a new method of applying zinc coatings. Lock-seamed joints, severe forming and drawing operations are all practical with sheets coated by the process and enable advantageous use of the material in the fabrication of various articles. Paint adherence to any zinc coated surface is also improved by a non-etching chemical treatment which does not injure the zinc surface.

ZINC COATING adherence surpassing that available in conventional hot dip galvanized sheet has been accomplished by the development of a process using entirely different equipment and methods. The zinc coating, which is composed almost entirely of commercially pure zinc, flows with the metal in forming operations instead of cracking and flaking away. Lock-seamed joints, which formerly were almost impossible to produce with galvanized sheets, as well as severe forming and drawing operations, are possible with the zinc coated product produced by this process.

Brighter surface, free from sal ammoniac spots, is another feature of this product, which is trade-named Zincgrip by American Rolling Mill Company. White zinc oxide stains, which occur when any zinc surface is subjected to moisture in the absence of air circulation, as in damp, unheated warehouses, are more noticeable on the brighter surfaces unless they are protected by a special coating, removable by hand cleaning or mechanical washing.

Because tight adherence of zinc makes possible severe forming operations, the material is suitable for fabrication by highly accurate production machinery. To satisfy thickness requirements of such machines the material has been made available on a decimal thickness basis similar to cold rolled sheets as well as on a weight per square foot or gage number basis. The material is also available in coils to meet a further requirement in this type of fabrication. Base metal may be ARMCO Ingot iron, copperbearing steel or ordinary mild open hearth steel. The physical properties of the base metal are somewhat higher than for ordinary galvanized. Various weights of coatings are applied by this method.

Deep Drawing

Severe drawing operations are accomplished without peeling or flaking. The same power, die metal, and draw rings as used for regular drawing steels can be used. The average clearance used in drawing cold rolled steel is suitable. In some instances a clearance slightly on the heavy side will compensate for the extra thickness of the zinc coating and produce a better drawing.

Two drawing lubricants are recommended: a light straw mineral oil and a half and half mixture of lard and paraffin oil. Others should be investigated thoroughly before adoption. They can be applied either mechanically by passing the blank through oiled rolls, or manually by spraying or brushing the compound on the metal. Hand application is generally more economical because it permits the press operator to determine the proper amount for best results. Blanks should be thoroughly oiled. Removal of drawing lubricant is generally not necessary unless the lubricant contains corrosive compounds or alkaline soaps.

Spinning

Spinning is accomplished with the same speeds, forms and tools as are used for copper, aluminum and other metals. Since Zincgrip is somewhat stiffer than other spinning metals, slightly greater pressures must be applied to the spinning tool.

A heavy bodied lubricant such as yellow laundry soap or beeswax should be used to protect the zinc coating against the pressures encountered. The soap can be removed by washing in water near the boiling point. Boiling water or steam will remove beeswax.

Average Physical Properties of Zincgrip

Tensile strength, lb. per sq. in.	45,000 to 50,000
Yield strength, lb. per sq. in.	35,000 to 40,000
Elongation percent in 2 in.	28 to 32
Hardness Rockwell "B"	54 to 62

Roll and Brake Forming

Channels, moldings, and other rolled shapes can be formed in the same roll forming equipment and with the same rolls, design and guides as used for mild steel. Forming rolls should be kept highly polished. Either naphtha or a light straw oil may be used as a lubricant. It is generally unnecessary to remove these lubricants after forming.

Brake forming can be performed on a hand or power brake with the same methods as used for mild steel. Ordinarily with polished dies no lubricants or protective coverings are necessary. However, at times it may be advisable to use a light lubricant such as straw oil, subject to working conditions.

Welding

Welding is practical for many applications and, by following certain precautions, with minimum damage to the coating. Zinc at the joint and adjacent to the weld is melted of course and some is vaporized and goes off in fumes. The portion of the sheet affected is not attacked as readily as uncoated iron or steel, but usually should be recoated. Protection is not diminished in the zone in which zinc was melted and then solidified. The method of welding may be metallic arc, carbon arc, oxy-acetylene, or resistance welding.

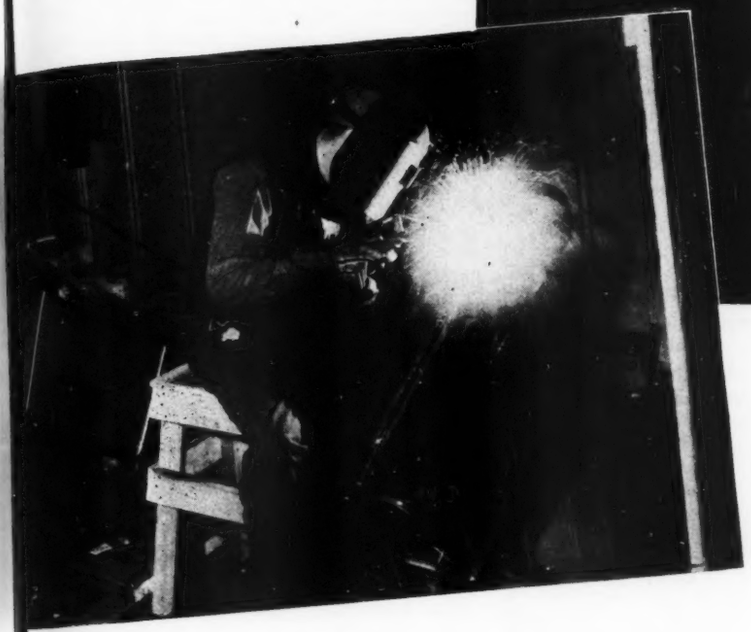
Jigs are necessary equipment for efficient operation. They prevent warping, conduct heat from the parent metal, and enable a more rapid, dense and

uniform weld. The jaws of the jigs should be close to the edges to be welded as is possible for good operation. and should press on the metal tightly enough to prevent excess expansion and contraction, but not so tight as to entirely prevent it.

Water-cooled jigs have been found not economically efficient. Jigs for oxy-acetylene welding are generally made of heavy angle iron or cast iron. In electric welding, copper chill bars must be used under the welded seam.

The metallic arc welding procedure, using mild steel shielded arc electrodes, is the same as is generally used for ordinary mild steel. Certain precautions are necessary to prevend a tendency toward making porous and unsound joints, which are thought to result from absorption of volatilized zinc in the molten deposited metal.

In carbon arc welding, carbon electrodes and a filler rod are required. Good results have been obtained with



(Above) Powder can heads 2⅜ in. deep are stamped from 16-gage Zincgrip by Porcelain Metals Corporation. This restrike operation forms the flange. Gradual accumulation of zinc on the draw ring is kept cleaned off to prevent imbedding of particles. (Left) Arc-welding of powder cans is speeded up by use of jigs

low melting point bronze filler rods. Since these rods require a low temperature for deposition, less sheet coating is oxidized during welding. Another rod, an alloy of copper, manganese and silicon carrying a tin composition coating has also given good results. Such a coating not only assists in absorbing the shock of the arc, but tends to flow to the sides of the weld and cover portions where the zinc was destroyed. Direct current is most suitable with carbon negative and work positive. Approximately 80 to 100 amperes are necessary for welding 18 to 20 gage material.

In oxy-acetylene welding there may be a tendency for the enveloping flame to burn off the zinc coating. Therefore, on 12 gage and thinner material, a heavy coat of thick paste brazing flux should be applied to each side of the sheet metal. Use of a jig with jaws as close to the joint as possible to conduct heat away and prevent enveloping torch flame from covering a wide area is advisable.

Spot welding requires about 25 to 50 percent higher welding current than would be used on cold rolled steel of the same gage. Shorter time and slightly higher pressures are also necessary to prevent burning the coating.

Since welding burns off the zinc and leaves a coating of scale and oxides which rust under corrosive service conditions, this surface must be restored. The weld area must be cleaned and then retinned or regalvanized. Spot welding, roller seam welding and butt flash welding all produce a narrow or small weld area with a minimum of oxide and are, therefore preferred methods.

Welding oxides are removed by three common methods: sand blasting, grinding with an abrasive wheel, and washing with acid or chemical solution. Five recoating methods are commonly employed: solder or "wipe," metal spray, paint, dip soldering, and coating powder.

Soldering

A 70 percent tin, 30 percent lead solder was generally used before the war for smooth joints requiring high impact strength. Higher tensile strength

is obtained with a low tin, high lead solder of about a 35-65 analysis. The high tin solders are more efficient, more expensive, and brighter in appearance. Cored solders, with ammonium chloride as the core, can also be used.

Satisfactory soldering is obtained by using as a flux either a cut (5 percent by weight) zinc chloride solution or hydrochloric acid cut with zinc. "Raw" acid or commercially pure hydrochloric acid also may be used as flux. Occasionally rosin is used but it is not as effective as the chloride fluxes.

Water Damage

Damage done by water in contact with zinc coated sheets is variable. Sheets may be stained superficially by the formation of zinc carbonate and zinc oxide or zinc hydroxide. However, under conditions where air is not allowed to come in contact with wet or moistened zinc coated sheets, such as when piled, the coating may be destroyed completely in a short time. Possibility of such damage must be avoided if the zinc coating is expected to give good service.

If zinc coated sheets are expected to remain uncorroded when stored horizontally in piles, they must be placed in a dry building in which a fairly uniform temperature is maintained throughout the year. Quick temperature changes cause "sweating" or condensation on the surface which will at least cause discoloration.

When stored in the open, or in damp and unheated warehouses, they should be placed on edge, slightly separated from one another to permit free circulation of air.

Cleaning

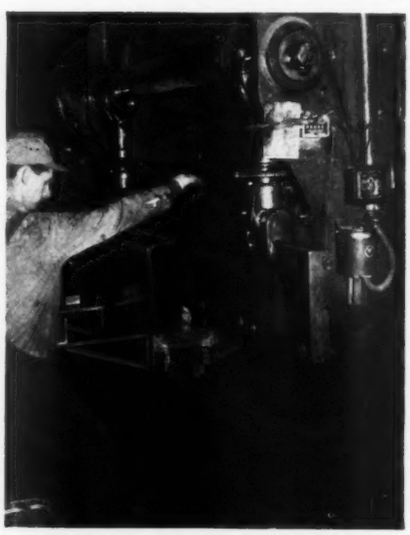
Cleaning methods depend upon the condition of the surface and the type of contamination to be removed. When only the thin film of oil placed on the sheets for shipping is to be removed a simple hand cleaning with a cloth soaked in mineral spirits, naphtha, or kerosene is satisfactory. Commercial degreasing machines are ideal for a production line. Emulsion type cleaners also give good results and are preferred for surfaces treated for painting. These cleaners should be removed by a hot water rinse. Quick and thorough drying prevents superficial staining or discoloration. Strong alkali or acid cleaners are not recommended on account of their tendency to stain or remove the bright surface.

Stains usually can be removed by washing and scrubbing with water. A cold 3-percent (by weight) chromic acid wash can be used for stains difficult to remove by water. A one percent solution of tri-sodium phosphate is also suitable. Cleaning should be followed by a hot water rinse, which will facilitate quick drying. Rust spots may be removed by rubbing with penetrating oil or by wire brushing. Methods of removing welding oxides are given with the discussion of welding methods.

To clean surfaces treated for painting, as described below, naphtha, benzine or lacquer thinners are preferred for hand cleaning. As an alternative, a good cleaner consists of a one to one mixture (by volume) of tertiary butyl alcohol and water. It is important that washed rags must be used because the sizing in new cheese cloth is soluble and leaves a residue, which can cause blisters after painting. Cleaning operations should be followed by a water rinse. Certain precautions should be observed if the water is hard.

Painting

The painting problem is about the same as with ordinary galvanized. The surface is difficult to "wet" with paint and paints will "age" if applied directly. A chemical treatment has been developed, however, which produces a finely crystalline zinc phosphate surface like fine sandpaper to which paint adheres firmly. This surface is neutral to paint, being neither acid nor alkaline, and is an integral part of the sheet. Since the average weight of zinc coating converted to phosphate is only 0.008 oz. per sq. ft. the zinc coating is not damaged as in acid etching. The smoothness of finish can be varied to suit requirements. A fine finish, however, tends to weaken the bond between the zinc and base metal.



A double-bending operation on the body of a zinc-coated powder can by a press brake leaves the coating undamaged

Fabricating and finishing operations of treated Zincgrip, known as Zincgrip Paintgrip, are practically the same as the untreated material. Lubricants used during fabrication must, of course, be removed by washing before paint is applied. The emulsion type cleaners are most satisfactory and it is essential that they be rinsed off with water followed by a chromic acid rinse.

The possibility of removal of the Paintgrip film at bends on double seaming, or at the corners formed in making a cabinet wrapper, is sometimes raised. The manufacturer's opinion, based on exhaustive laboratory tests, is that even through a small portion of the film may be removed, the action of the treatment on adjacent sides is sufficient to preserve paint elasticity. In other words, the drying-out action of zinc is believed to be confined to such a small area that there will not be enough aging to offset the insulating value of the film at each side. However, when designers wish to be particularly cautious, another application of the treating solution can be applied by the fabricator on the corners or bends.

Welding and soldering procedures are practically identical with untreated Zincgrip with a few slight changes technique.

Treated sheet should be stored in a dry room maintained at normal room temperature. The phosphate surface will absorb moisture which, if not thoroughly removed before painting, will cause early paint failure. Removal is easily accomplished by heating to 225 to 250 deg. F.

Practically any good paint system can be applied after bonderizing treatment. Many paint manufacturers supply special galvanized iron primers which have considerable merit. Any good baking system is satisfactory provided the baking temperature does not exceed 450 deg. F.

Paint can be removed without damaging the film by means of a solution consisting of 16 lb. ethyl acetate, 16 lb. grade D alcohol, 16 lb. benzol, and 8 lb. paraffin. This solution should be heated to 130 deg. F. and applied at that temperature.

At least three methods are available for removing paint from small articles. The first method consists of dipping the article in a vapor degreaser. There are three steps in the second method. Strip the paint with a 5 percent solution of boiling caustic soda by dipping. Rinse in cold water and dip the article into a 2 percent solution of chromic acid. The third method employs a patented dipping solution.

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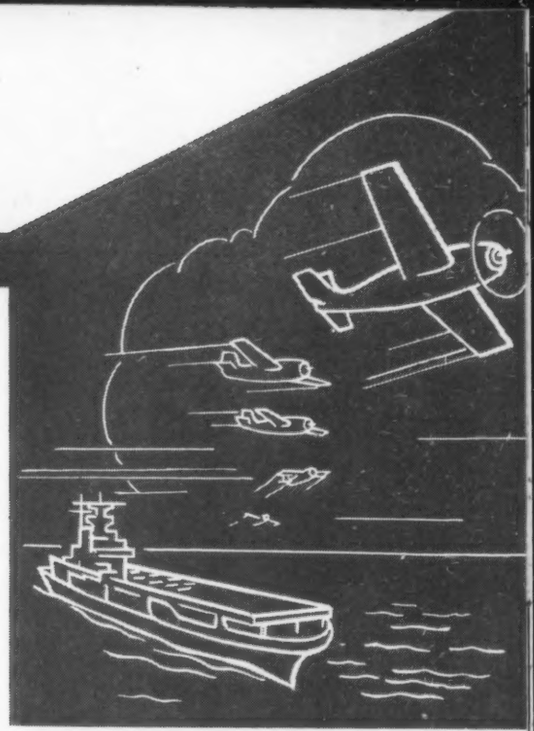
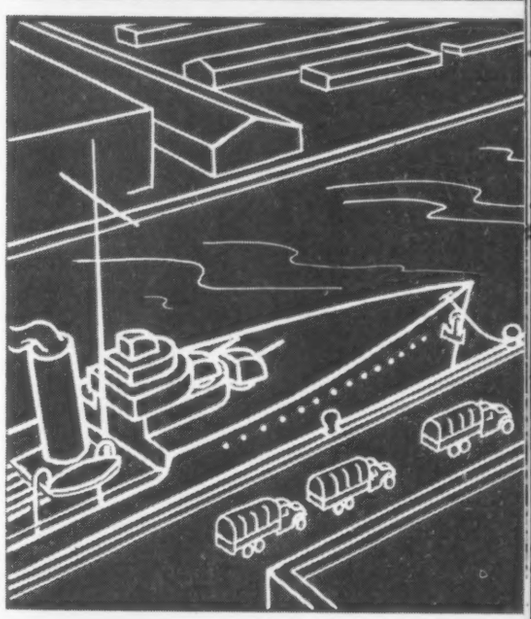
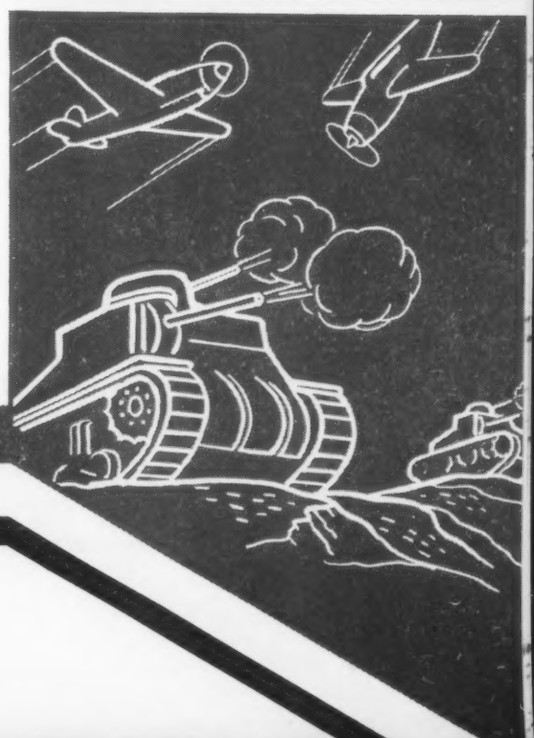






U. S. Army Signal Corps

Anti-tank battery. To "keep it firing" consumes materiel that can be made only by the most modern production processes

Design and Redesign of Ordnance Materiel

J. B. NEALEY

In tune with scientific and industrial progress, the Ordnance Department has been carrying on quietly an aggressive program in the adoption of new materials and new manufacturing processes. A few of the most significant developments are set forth in this article.

THE EFFECT of the enormous program of redesigning war material now being carried on by the Ordnance Department of the U.S. Army is already being felt in various sections of industry. The overload of war orders on some types of manufacture is already being relieved by shifting contracts over to other types of plant which were down or only partially operated because of lack of work. Conservation of critical materials is being effected in a large way.

Naturally a large volume of the items contracted for are in the form of forgings and steel castings. One of the heaviest of these items, artillery gun barrels, was made exclusively by the forging process until recently. A large portion of this burden has now been shifted to the foundry through the design and engineering of suitable centrifugal casting molds. Today gun barrels running from one to five inches in calibre are produced in this manner. This, together with the development of the autofrettage or cold working method of strengthening the steel, completely changed the cannon design in those sizes affected.

In other words, the cast monobloc gun tube with rifling cut directly into it is replacing the built-up gun of yore. Formerly all cannons consisted of a forged tube onto which were shrunk hoops and bands to increase its strength. The larger sizes still are made this way but the smaller sizes are slim tubes of one-piece construction and are made so quickly and cheaply that extra tubes are carried in the field for easy replacement when those in use become worn. While this changeover predated the current program of redesign it is an outstanding example because a single casting machine will turn out several gun tubes in the time it takes to forge one, and subsequent machining is reduced materially. The saving in steel is enormous.

On the other hand, the stamping industry and also some types of foundry have been suffering for orders and this new program is of immense benefit to them. Every redesign, however, is carefully engineered as the result of studies involving the following factors: (a) production quantity; (b) machine load

and capacity of present and proposed methods; (c) material, specifications and availability; (d) maintenance of functional standards; (e) engineering, testing and proving.

Utilizing high-tensile steel and brazing or welding the parts together, seemed to be the answer for those metal stamping shops equipped with modern forming, drawing and embossing presses. This proved to be the case and on some redesigned parts there was less scrap loss, a reduction in weight and an increase in production per man-hour.

Take for instance the windshield used on most armor piercing shot to give them the proper streamlining for maximum range. Formerly they were die-cast from aluminum but they have been redesigned and are now drawn from sheet steel in presses. Bomb parts such as tail fins, nose and tail plugs, fin lock nuts, adapters, etc., are now made from steel stampings.

A shift from forge shop to foundry was made by redesigning a number of machine gun parts so that they could be cast in iron and malleablized. This also effected an appreciable saving in machine tools and machining time which helped to increase machine gun production. One of the largest malleabilized castings producers in the country is now utilizing a section of one of its foundries for casting 60 mm. trench mortar shells. Shells containing high explosives are used with practically all artillery and trench mortars. The tonnages being used today are enormous and these shells are being forged, pierced and drawn, cast and spun.

High-explosive shells are hollow to receive the charge of explosive and the walls are of a sufficient thickness to afford the greatest effective fragmentation. In other words the design is such that when the shell explodes it breaks into hundreds of pieces which fly in all directions at high velocities and are very destructive. Functional standards are a big factor in shell design. While trench mortars are smooth bore short range weapons employing only a small charge of propellant, long range artillery guns use much greater charges and are rifled. Therefore the stresses brought to bear on artillery shells are of a much higher order, so much so that porosities undetected by shop inspection, might prove dangerous. Hence few artillery shells are being cast as yet.

In setting up specifications for the casting of the mortar shells, wall dimensions and close tolerances were the main factors. No steel specification or chemical analyses were given the contractor but instead it was up to him to produce a steel that met certain fragmentation requirements that had already been ascertained by ordnance engineers. These were that the shell case, when blown apart by its explosive charge should break up into pieces of such an order that 80 percent of them would be retained by a four mesh screen. The company involved finally produced a steel in its electric furnaces and developed a triple heat-treatment to give it the required physical characteristics. The steel being used has a minimum yield of 35,000 lb. per sq. in., with an elongation of 30 percent in two inches and a reduction in area of 50 percent. This emphasizes the need for the design engineer to know his materials, their scope and limitations.

Comparative results of one method as against another are always interesting. In this matter of high-explosive shells, almost half are being produced today by the hot pierce and draw method and close to 40 percent are being forged by the upsetter process. However, casting offers distinct possibilities and improved foundry practice will no doubt extend this method of producing them. In the foundry under discussion from 9,000 to 10,000 trench mortar shells are cast with only three molding machines, every day, 24 hours. Now by using the pierce and draw, or upsetter, method no such results are obtainable. An installation consisting of two presses, one draw bench and a rotary furnace will produce close to 4,000, possibly 4,200 shells, 105 mm., a day. An installation including two upsetters and a furnace would hardly duplicate this.

Foundries equipped with electric furnaces for steel melting have found themselves loaded with orders for cast armor plate due to our enormous tank program. These orders are in addition to the already large commitments for artillery, combat vehicles, etc., and made steel castings a critical item. Gray iron foundries for the most part with large idle capacity are on the hunt for orders and it has been suggested that they install Bessemer converters. This innovation, together with a slight change in molding sand, would put them on the list for steel casting contracts. This is only a suggestion, however, for previous to the present critical situation Bessemer steel was thought to be too brittle for war ma-

Centrifugal casting machines used for the manufacture of cast steel artillery gun barrels

Cast steel barrels, cold worked to improve their strength, have revolutionized the manufacture of artillery guns

teriel. Ordnance engineers are now conducting research with a view to extending the use of that metal.

The lug for a certain type of bomb was once forged and machined but it was so redesigned that it is now being stamped from steel. Not only did this put idle stamping capacity to work but it saved 1,700 lb. of steel and 8,000 machine-tool hours on a single lot of 100,000 bombs. This adapter was a smart ordnance idea by which the large number of sizes of fuzes was materially reduced. One of these adapters weighed only 1.81 lb. but was machined from a 3.85 lb. steel bar at the expense of 0.23 manhour. Redesign permitted its manufacture from pressed steel with a little brazing. Something like 3,000 tons of steel and 210,000 machine-tool hours will be saved by this change and 25 screw machines will be released for other more critical work. For brazing 3,500 lb. of copper will be required.

On the other hand, certain advantages are obtained by changing some items over to forging. An outstanding example of this is the 37 mm. armor piercing shot used with tank guns. While many armor piercing, A.P., shot are turned from bar stock in lathes, single-purpose machines and automatic screw machines, a forging technique has been developed that produces a superior projectile with a 30 percent saving in material.

With the advent of modern armor plate of alloy steel, face hardened and with a tough core, the then standard armor piercing projectiles went out. Ordnance engineers got busy and redesigned, tested and perfected new ones. These had two conflicting design characteristics, a sharp nose for long range and a blunter nose for maximum penetration. Reconciliation was obtained by designing the shot for penetration and then adding, to some types, a false nose called a windshield to effect the streamlined ogive. A cap is also added to the nose and under the windshield which improves the penetrating qualities of the shot.

While this bit of military design compromise is interesting it is not the design of the 37 mm. A.P. shot that is now being forged. This 37 mm. projectile, as stated, is for tank warfare which is conducted at comparatively short ranges and therefore does not require the cap nor the windshield. In redesigning this item for forging it was recognized that the poorest structure in bar stock is the center. The most important part of an A.P. shot is the nose or point and when machined from bar stock this might constitute a weakness.

Design engineers of an Ohio plant working with Ordnance officers developed a forging technique by which the shot are now being made. This technique reworks the hot steel so as not only to eliminate any voids that might be present but also arranges the grain flow to converge at the nose in a hard, tough knot, with superior penetrating qualities. Proof of its excellence is that all shot so far produced and submitted for ballistic tests have been accepted. The plant has produced its first million and is well toward completion of its second million.

This shot weighs 1.91 lb. and raw material in the form of $1\frac{7}{8}$ in. round, hot rolled steel bars is employed. The shot is smaller in diameter than the bar itself but the full diameter is attained in forging and the surface is cleaned in a centerless grinder. There is a saving in metal here as against the machining process which formerly removed $\frac{1}{8}$ in. metal. Again all metal hogged off the nose of the bar by machining is saved by forging. Lastly, the forging billets are sheared from the 14 to 16 ft. bars without loss of metal as contrasted with a loss of from $\frac{1}{4}$ to $\frac{3}{8}$ in. from the face of the bars when the shot are cut off in machines. This all adds up to a total saving of at least 30 percent in material.

The practice worked out is of interest and consists of heating the sheared billets to 1,700-1,800 deg. F. in a rotary gas fired furnace and feeding them to two Consolidated presses fitted with forging dies. Forging is accomplished with one "hit" and the

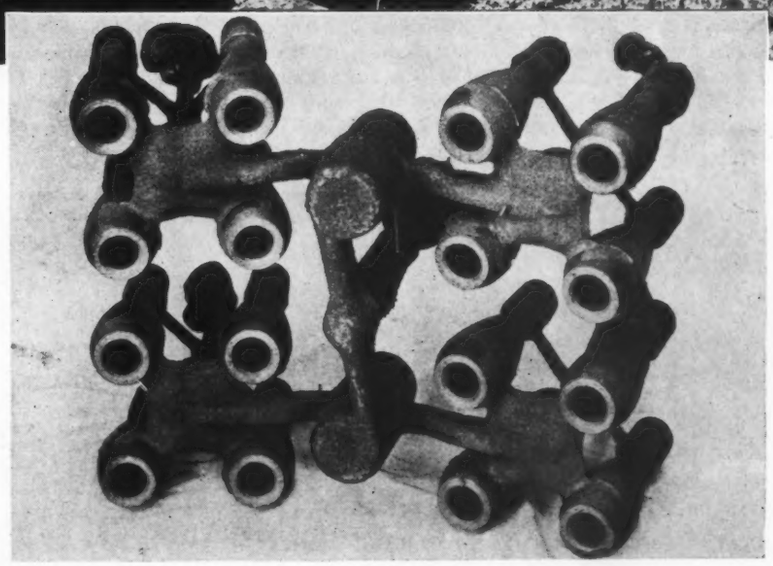
steel is forced into the nose to insure uniformity, and to prevent "tear drops" extra material is pushed into a lug or nib extending from the nose. This nib is ground off. After heat-treating, the forgings then pass down a long line of machines for various machine operations.

After machining the shot are given a final heat-treatment the details of which are of particular interest to the design engineer. In ordinary fuel fired furnaces these steel shot increase in diameter and decrease in length. By using the electric induction method a reverse effect is obtained and when machining it is easier to allow for the second set of changes than the first. Also the induction method is more economical of material. Tocco machines are employed and each consists of two holding fixtures, coil sets, quenches, etc. so that a single operator can load and unload one while the other is in operation. A predetermined time cycle of 90 sec. is used with automatic operation. Six shot are loaded into the first fixture and a motor raises the whole into the coils above. Here they attain temperature and are then quenched by water sprays while the shot are still in the coils. Drawing is accomplished in an ordinary type continuous furnace.

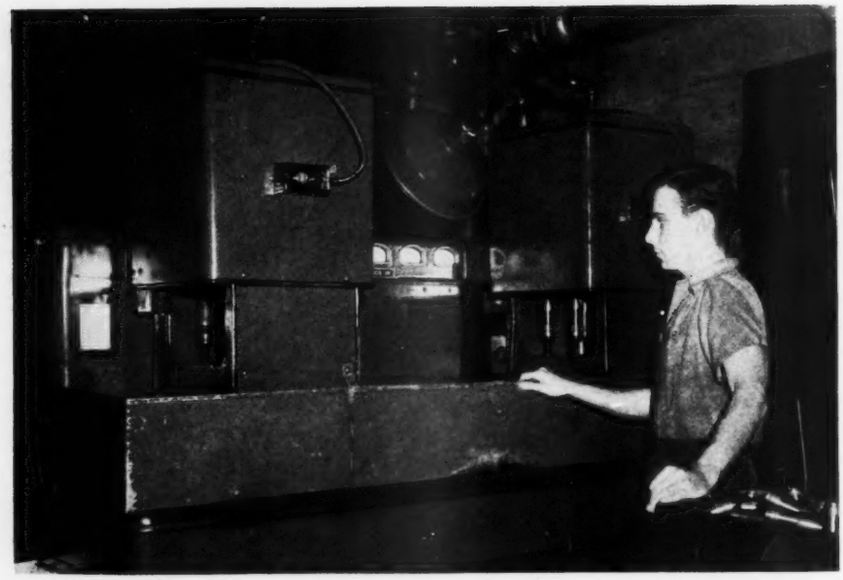
Mobility and the need for high angle fire guns caused the Ordnance Department to develop an entirely new type of gun carriage. New and practical designs were successfully developed and put into mass production. Full advantage was taken of the welding process in designing the carriages and mounts to simplify their manufacture and decrease their weight. This was accomplished by substituting built-up welded structures in place of the heavy cast-steel parts. The carriage is a lot harder to make than the gun as can be visualized from the fact that between 4,000 and 5,000 drawings are required in the manufacture of an anti-aircraft carriage as against only 300 or 400 for the gun itself. Today most of the parts of these complicated structures are cut from plate steel with a torch and assembled by welding. This eliminates the long process of preparing molds and cores, melting, iron, pouring, cleaning and machining castings. It also saves metal and makes the carriage lighter.

In one plant producing the 90 mm. anti-aircraft gun mount weldments are sectionalized and progressive straight line production methods are used where possible. Each of the subassemblies is so jigged as to keep the parts in strict alignment with full allowance for distortion and shrinkage. The work is mounted on power-driven positioners

U. S. Army Signal Corps



Mortar shells are now produced as steel castings heat-treated to attain the required physicals. Production is much faster and forging equipment has been released for other jobs



Induction heating makes possible the hardening of shell noses on a mass production basis with exact automatic control. Time and labor required are practically negligible

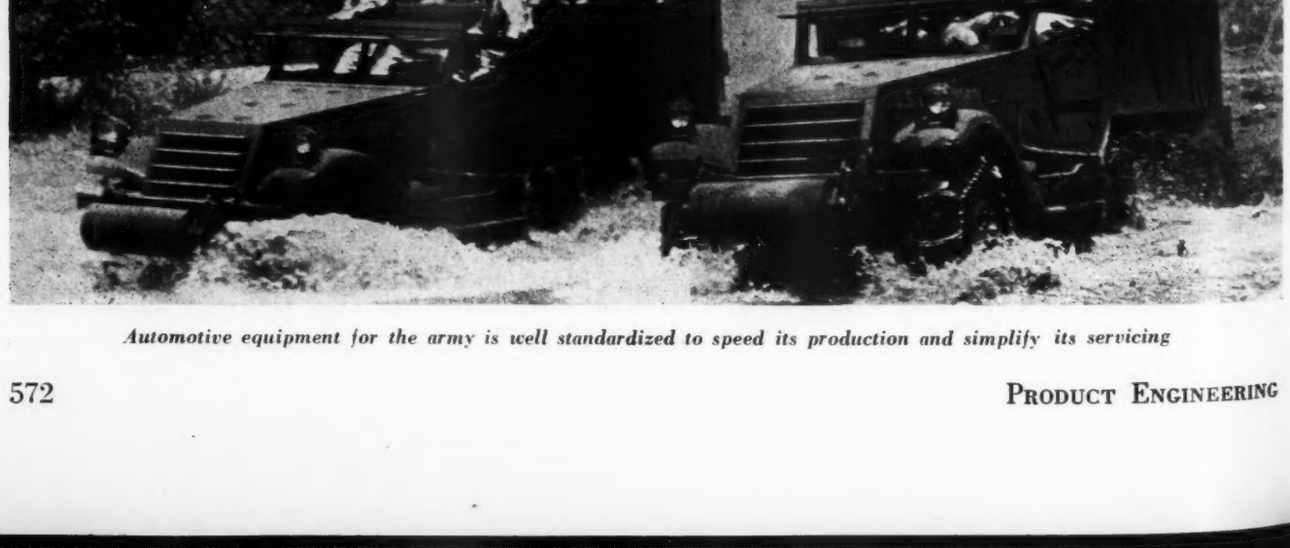
that can be turned in any direction so that the welder can do his work in the most favorable position, using down hand welding. Electric welding is employed throughout and a.c. in preference to d.c., as it is here considered better and faster. Design strength and rigidity were obtained and steel plate conserved by using box and U-sections where possible.

As to what the design engineer lets himself in for when specifying welded construction for the military, the following is very enlightening. First off, and starting with the smaller weldments, the welds are cleaned by shot blasting for visual inspection. Then they are subjected to a Magnaflux inspection, and all faulty welds marked and repaired. The welds are then X-rayed by a machine that will penetrate 1½ in. of steel. The pictures are taken with exposures running from 10 to 120 sec. according to the thickness of the work. All defective welds are chipped out and rewelded. The X-raying is done in a room with 10-in. concrete walls and the doors are covered with sheet lead ⅛ in. thick. Roentgengrams of the work are made at the points of greatest stress and the number of pictures to be taken is determined by ordnance engineers.

Cooperative Design

One of the most difficult feats of engineering design for all time was that of the army's fast half track car and personnel carrier. The specifications laid down at the beginning by the Ordnance Department were difficult and required a super-engineering effort to meet conflicting demands. Lightness for mobility and speed were essential; but just as necessary were heavy armor plate for safety, armament for protection, heavy construction for durability, a large power unit for propulsion. In addition to negotiating rough and soft terrain the vehicles must ford streams, bridge trenches, climb in and out of shell holes and ditches. They must combine high clearance with low, over-all target height. High acceleration must be balanced against an extremely low horsepower-to-weight ratio, and yet there must be sufficient horsepower to pull through mud, sand and marshland.

While the bodies of the car and personnel carrier would necessarily vary in design, the other parts such as chassis, engine, transmission, wheels, half track, etc. all could be made alike. What this would mean in maintenance would be immeasurable. It could possibly be the deciding factor in battle when the early determination of enemy position or the delivery of soldiers and supplies depended upon quick repairs to disabled cars. Multiple types with multiple stocks of repair parts in the field were therefore ruled out, and a single design adopted. The executives and engineers of three companies were called to Washington by the Ordnance Department and asked to work together on a single design that could be produced in all three plants concurrently. Notwithstanding that these three companies were highly competitive in the field of light and medium-weight trucks, the cooperation they gave the Ordnance Department is a milestone in friendly and intelligent collaboration. In a remarkably short time the designs and specifications had been reworked, mock up models made, bugs squashed and the cars were rolling off the assembly lines. So closely were the specifications followed that cars from all three plants can be taken apart, the parts scrambled and put together, and the assembled cars will operate as well as the originals.

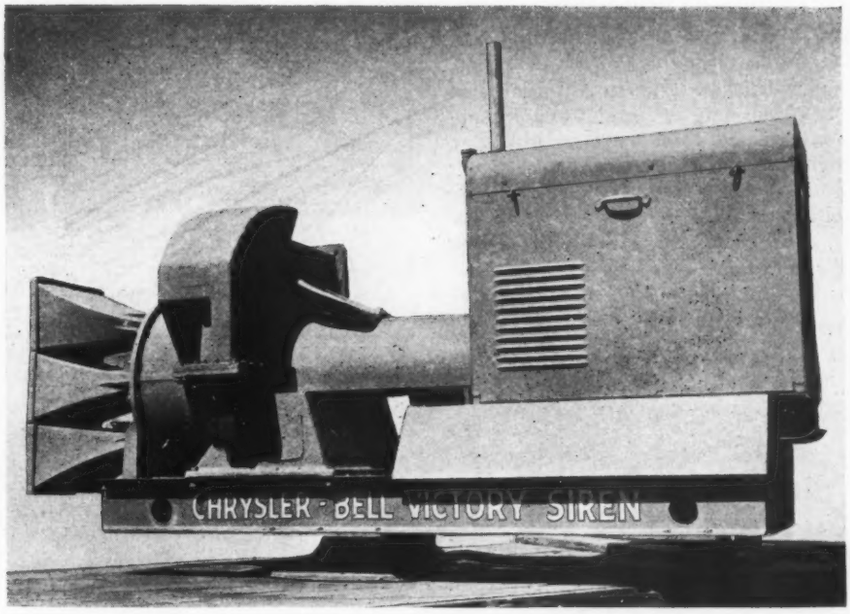


Automotive equipment for the army is well standardized to speed its production and simplify its servicing

WARTIME DESIGNS . . .

CHRYSLER-BELL VICTORY SIREN REQUIRES LESS CRITICAL MATERIALS

When O.C.D. needed a tremendous noise-maker for air-raid warning systems, they turned for help to scientists of O.S.R.D., who decided to concentrate on a development in progress at Bell Laboratories—a new, efficient siren principle capable of producing an infernally loud noise. Bell speedily built an experimental model, obtained excellent test results. Chrysler Corporation then took over for production and put finishing touches on the design. Result: this engine-driven, 140-db. siren, thoroughly capable of making itself heard in our biggest cities.



How Loud Is the Victory Siren?

AN INCREASE OF 10 DECIBELS means 10 times the sound; an increase of 20 db. means 100 times the sound; etc. Normal conversation is 60 db. Heavy street traffic is 90 db., Inside some tanks the level is 115 db., as is the value for a racing airplane propeller and motor measured at 15 ft. At the throat of the Victory siren the sound intensity is 170 db.

SIRENS ARE RATED by decibels measured at 100 ft. A good electric siren produces 110 db. Victory siren has 140 db. rating—1,000 times as powerful as a high-grade electric siren.

SOUND WAVE with a pressure variation only 1 billionth of atmospheric pressure is audible. Thunder has a pressure variation of 0.01 percent. Ordinary sirens have pressure wave variations ranging from 1 to 10 percent. The Victory siren's sound wave produces a pressure variation of 30 percent.

IN A CHRYSLER 8 AUTOMOBILE traveling at 30 m.p.h., sound power entering a passenger's ear from the engine is 0.000.000.001 hp. By contrast, the same engine driving the Victory siren produces 40 hp. sound power.

REDUCTION OF 5 DB. in siren rating reduces area of effective coverage by half. On this basis, one Victory siren will cover an area that would require 120 electric sirens—at a cost of 1/10 that for electric sirens.

TABLE PREPARED BY O.C.D. shows that it takes 500 to 2,500 sirens of 100-db. rating to cover an area of 50 sq. mi. with the necessary 70-80 db. signal level. The job can be done by from 2 to 17 Victory sirens, depending on nature of the terrain.

WHAT THIS MEANS IN MATERIALS: To protect an area of 15,000 sq. mi., Victory sirens would require less than 1,300 tons of steel; electric sirens would require 10,000 tons. Victory sirens would require 65 tons of copper; electric sirens, 260 tons, not including circuit wiring. Victory sirens would need 14 tons of zinc alloy; electric sirens, 4,800 tons. Principal material in Victory sirens is cast iron, of which 7,800 tons would be required as against none for electric sirens.

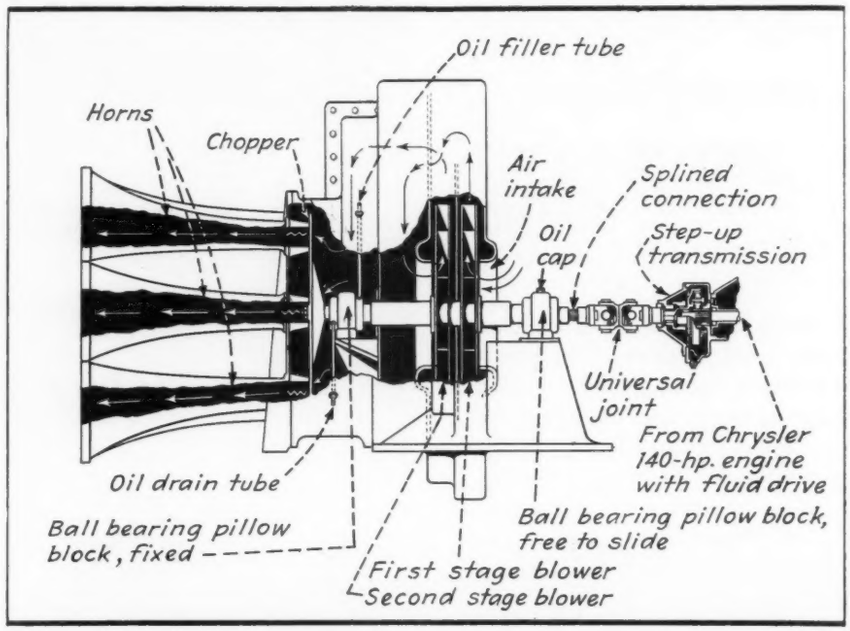
EXPERIMENTAL HORNS made of plywood were found to be charred after a test run. Frictional heat generated by the intense sound vibrations was too great.

WELDED STEEL HORNS were tried next. Sheets 0.040 in. thick were spot welded, with welds 1 in. on centers. Reinforcing ribs 1½ in. apart were welded around the horn. During test runs, the vibration build-up became so great that the horns flew apart. Cast iron horns with $\frac{3}{16}$-in. walls are successful.

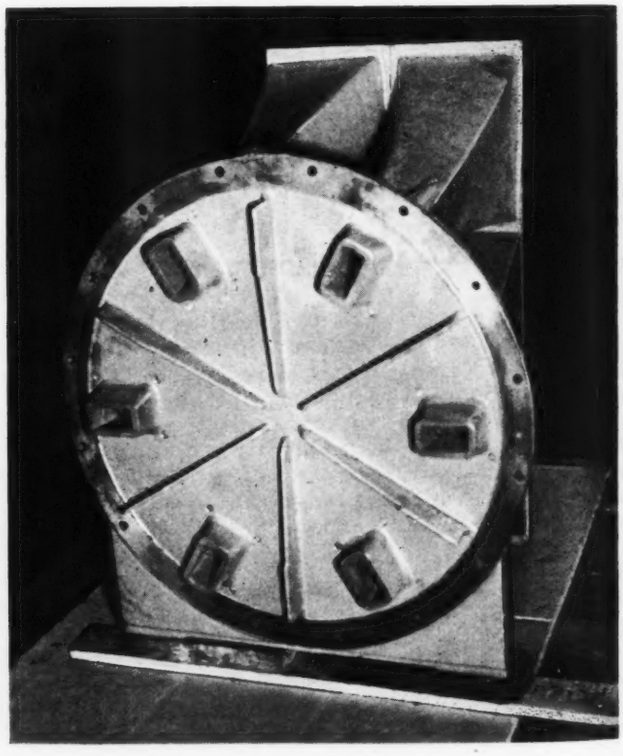
(Continued on next page)

CHRYSLER-BELL VICTORY SIREN (continued)

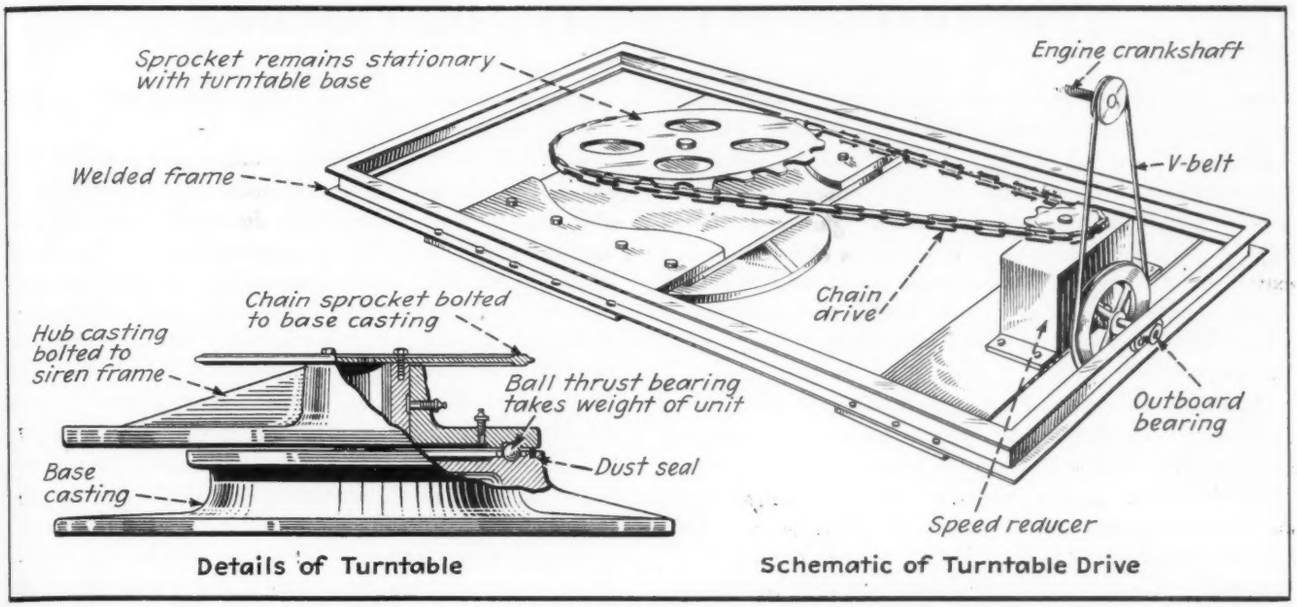
Victory siren creates noise by high-frequency disturbance of air, achieved by means of a "chopper" disk rotating across the openings of six rectangular horn throats. Compressed air from blower is introduced behind the chopper, and as it rushes through the horn throats, is "chopped" off by revolving blades, thus setting up variations in pressure. Standard Chrysler 8-cylinder, 140 hp., skid-mounted engine drives blower, chopper and turntable, and is entirely independent of local power supply. Top engine speed is 3,400 r.p.m., but planetary step-up transmission (1.308 speed-up) gives blower and chopper a speed of about 4,400 r.p.m. Engine and transmission are connected through Fluid Drive so that engine can idle without actuating the siren. Universal joint connects transmission and blower shafts. Engine has electric immersion heater for cold starting. Fuel tank, 18-gal., is mounted with engine unit.



Blower is centrifugal, two stage, with cast iron body. Capacity is 2,500 cu. ft. per min. at 5 lb. per sq. in.—an unusual capacity necessitating special design with help of American Blower Corporation. Steel rotors are balanced for all dynamic forces. Chopper blade is shown above at end of rotor shaft. It is 25-in. dia. bladed disk, is machined to close tolerances. Gap between chopper and horn throat openings is 0.004 to 0.010 in. Castellated nuts on blower assembly are wired to prevent loosening.

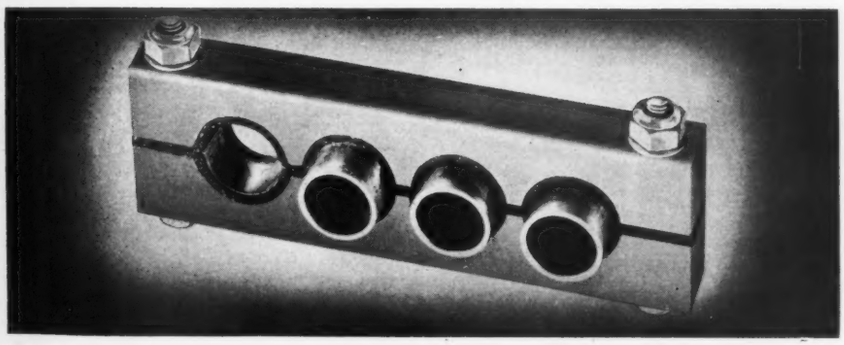


Horn assembly consists of throat plate and six horns bolted into rigid unit. Material is cast iron with high percentage of steel scrap for good resistance to low sound frequencies. Horns are exponential type. Top and bottom horns have slight twist because throat holes are cored at angles. In earlier design, the six horns opened into one large exponential horn, but tests proved six separate and adjacent horns gave better results. Beam of sound has 90-deg. horizontal spread 45-deg. vertical spread.



Turntable assembly rotates siren once every 2 min. Drive is through V-belt from front of engine crankshaft, through standard gear speed reducer and chain drive to large sprocket which is bolted to turntable base. Frame is welded I-beam assembly with steel plates bolted to beams for support of gear reducer and for mounting frame on cast hub of turntable. Weight of siren is supported by large ball thrust bearing. Advantage of rotating beam of sound is that a given amount of equipment can thus cover 3 to 6 times the area that could be covered by stationary 360-deg. non-directional unit. Rise and fall of pitch is now achieved by snapping the ignition on and off; experiments are now under way to develop a new "warbling" method. Siren can be operated manually or remotely.

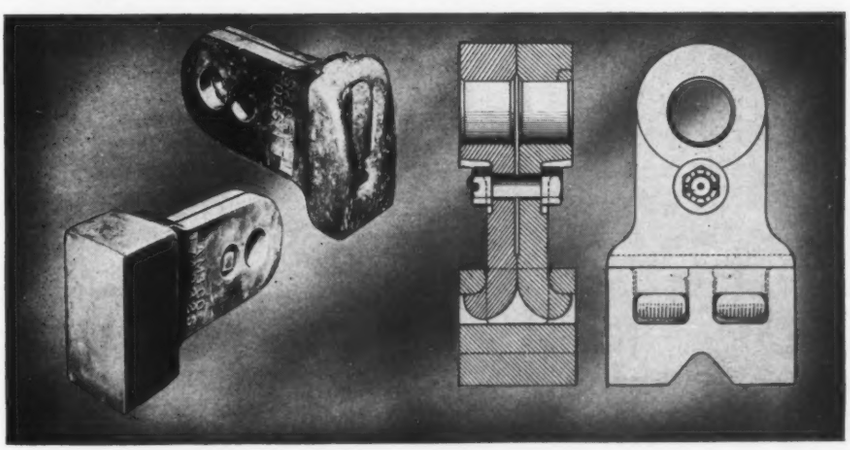
THIN STRIP REPLACES THICK BLOCK OF RUBBER



By using a plastic block with a thin strip of synthetic rubber compound (adelite) instead of a thick block of rubber, this new multiple line support for aircraft uses 88 to 94 percent less rubber material. In each plane, 40 to 250 of these batten down fuel, hydraulic and electric lines, protecting them from vibration and grounding them. Adel Precision Products Corporation says the plastic supports are not quite as good as previous synthetic rubber blocks, but are good enough.

RENEWABLE TIP CONSERVES MANGANESE STEEL

When two-thirds of head of Clark renewable tip pulverizer hammer is worn away, it is discarded, but design feature permits reuse of arm, which can be removed from the head. Arm consists of two bars with hooks on their lower ends which engage in internal pockets in head. Bars are bolted together under the eye to form a one-piece unit. Assembly bolts take no operating stress. Hammer shown in photo weighed 110 lb. new—all manganese steel. When replacement was necessary, only 16½ lb. remaining of the head was scrapped. Arms still serviceable weighed 57 lb. Drawings show another type with larger shaft bearing.



LINK TRAINER SAVES WITH DIE-CASTINGS

NEED FOR CONSERVING ALUMINUM except where light weight is essential, as well as a desire to reduce production costs have led Link Aviation Devices, Inc., to substitute zinc alloy die-castings for many parts previously sand-cast of aluminum alloy. Transition from highly critical aluminum to less critical zinc alloy is extremely important to war economy, but in some respects is less significant than savings realized in labor, number of machining operations, and consequently in the number of machines needed.

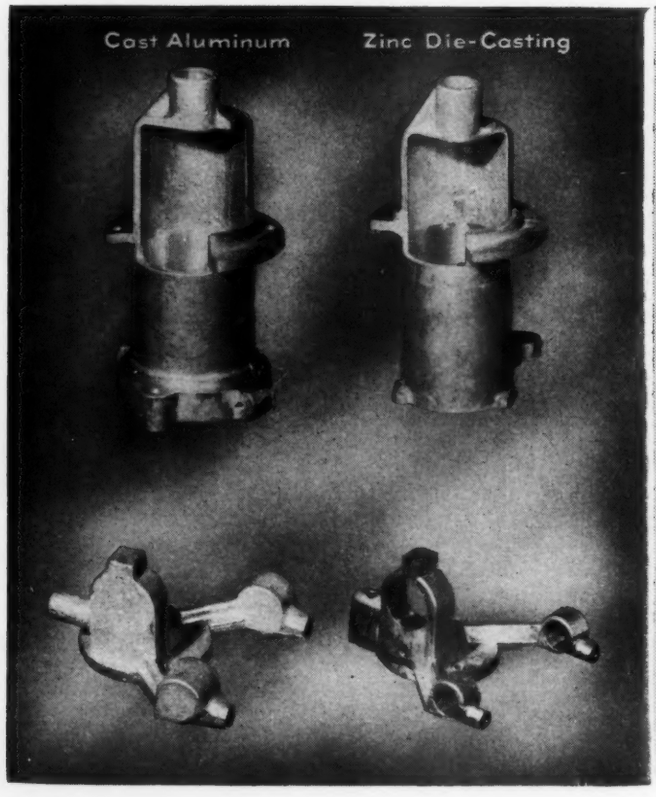
Although die costs are an important factor, mass production is not always necessary to justify die-castings economically. Precise cost figures given below for five of the Link trainer parts demonstrate that die-castings may be economical even when moderate quantities are required. Dies for a set of eight Link trainer parts cost a total of $5,175. Cost per set of die-castings fully machined in quantities purchased is $17.58. The cost of a corresponding set of aluminum alloy sand-castings completely machined was $42.08, or $24.50 more expensive per set than die-castings. Thus the saving on only 211 sets of die-castings is sufficient to pay for the dies.

Figures are not always favorable to die-castings, of course, but it is stated that these parts are by no means exceptional. An analysis of the costs given for the five parts below shows that rough aluminum sand-castings average about 2½ times as much in cost as corresponding unmachined zinc alloy die-castings. In addition, machining the aluminum costs nearly 2.4 times as much as machining the zinc die-castings.

Reasons: Foundry operations for sand-castings are slower than die-casting, and labor charges are proportionately higher. Many holes which are readily cored in die-castings cannot be cored in sand-castings. In sand-castings, equally close dimensions cannot be held and surfaces are rougher than for die-castings; hence machining allowances for sand-castings must be greater. Sections for aluminum sand-castings are necessarily thicker than for die-castings. Die-castings, being thinner in section, may be slightly less rigid, but can be ribbed to compensate for this. Most of these factors are illustrated in the drawing of the Left End Frame shown opposite, comparing the designs for cast aluminum and zinc die casting.

Many of the economies attained with the zinc alloy die-castings could also have been realized with aluminum die-castings, although this would not have saved so much aluminum. Past experience shows that die costs for aluminum exceed those for zinc and that the cost per part for aluminum die-castings nearly always exceeds that for zinc die-castings, especially when the parts or designed for equal strength.

Light weight is not essential for most parts of the Link trainer, since it does not leave the ground, but light weight is necessary for some of its parts in which inertia is a factor. In such cases aluminum die-castings have been specified.



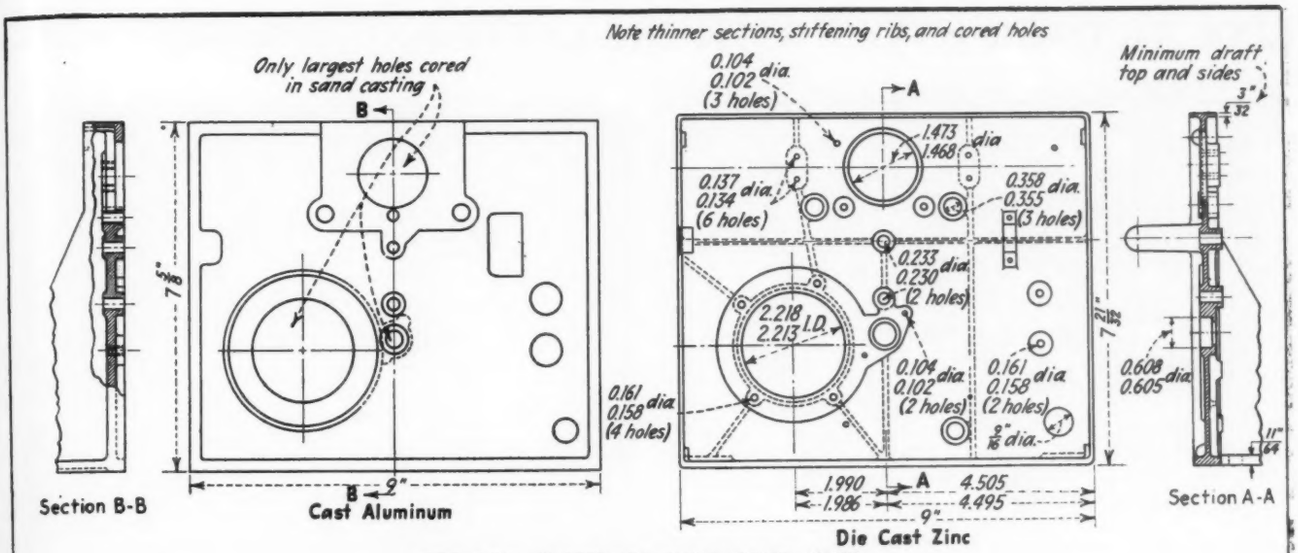
AUTOSYN HOUSING

	Aluminum Sand-Casting	Zinc Alloy Die-Casting
Weight	13 oz.*	15 oz.
As-cast cost per piece	$ 0.95	$ 0.26
Machining cost per piece	5.51	1.80
Total cost per piece	6.46	2.06
Cost of die	—	$730.00
Approx. avg. section thickness	7/32 in.	3/32 in
Holes	Axial holes cored	Mostly cored

*As machined with separate end ring shown at bottom of part in photo. This ring was eliminated in die-casting by integral lug.

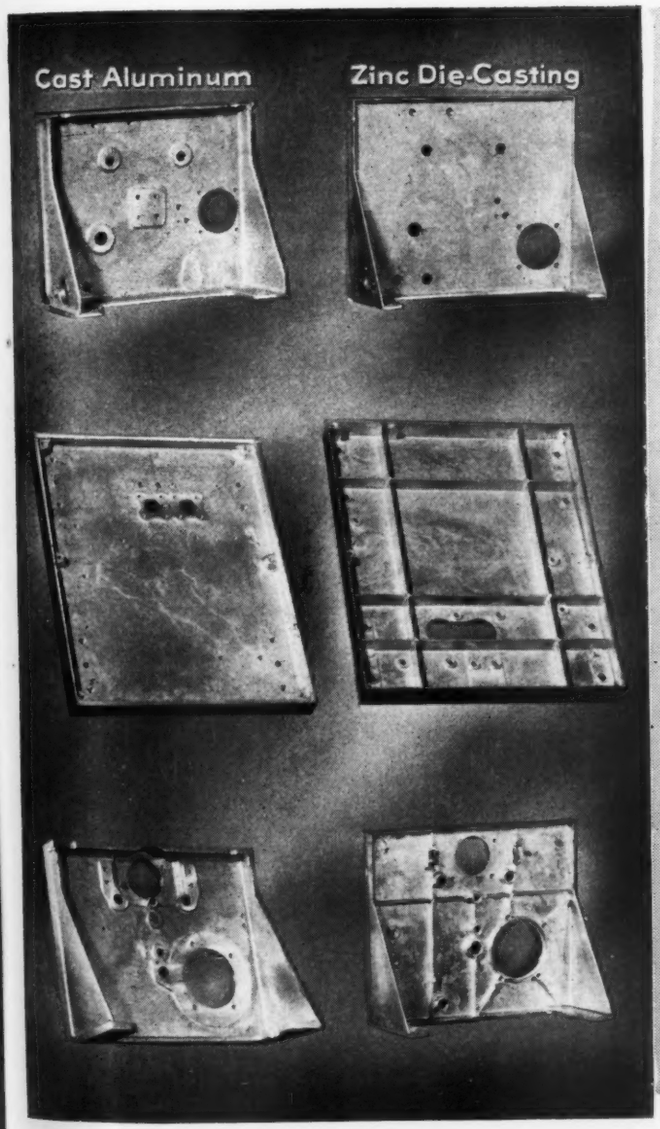
UPPER CARRIAGE FRAME

	Aluminum Sand-Casting	Zinc Alloy Die-Casting
Weight	7 oz.	7 oz.
As-cast cost per piece	$ 0.38	$ 0.11
Machining cost per piece	4.70	2.10
Total cost per piece	5.08	2.21
Cost of die (combination for 2 parts)	—	$775.00
Approx. avg. section thickness	3/16 in.	3/32 in.
Holes	None cored	Mostly cored to reaming or tapping size.



LEFT END FRAME OF WIND DRIFT UNIT

See below for Cost, Weight Analysis



WIND DRIFT UNIT

Right End Frame

	Aluminum Sand-Casting	Zinc Alloy Die-Casting
Weight	2 lb. 7 oz.	2 lb. 7 oz.
As-cast cost per piece	$ 1.74	$ 0.78
Machining cost per piece	4.66	2.20
Total cost per piece	6.40	2.98
Cost of die	—	$775.00
Approx. avg. section thickness	3/16 in.	3/32 in.
Holes	Only 2 largest holes cored	Nearly all cored to reaming or tapping size

Base

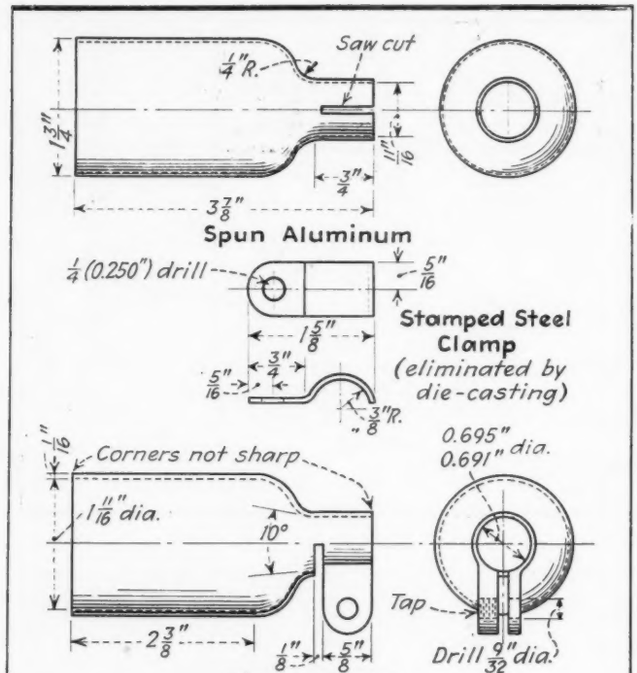
	Aluminum Sand-Casting	Zinc Alloy Die-Casting
Weight	3 lb.	4 lb. 3 oz.
As-cast cost per piece	$ 2.37	$ 1.02
Machining cost per piece	5.08	1.65
Total cost per piece	7.45	2.67
Cost of die	—	$860.00
Approx. avg. section thickness	5/32 in.	3/32 in.
Holes	Only two largest holes cored	All cored to tapping or reaming size

Left End Frame

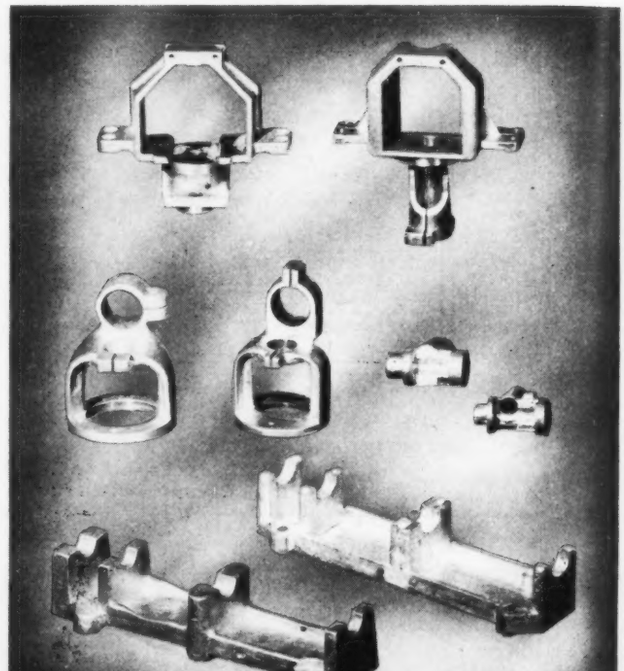
	Aluminum Sand-Casting	Zinc Alloy Die-Casting
Weight	2 lb. 6 oz.	2 lb. 13 oz.
As-cast cost per piece	$ 1.90	$ 0.83
Machining cost per piece	5.10	2.80
Total cost per piece	7.00	3.63
Cost of die	—	$915.00
Approx. avg. section thickness	3/16 in.	3/32 in.
Holes	Only few largest holes cored	Nearly all cored to reaming or tapping size

(*Continued on next page*)

LINK TRAINER SAVES WITH DIE-CASTINGS (continued)



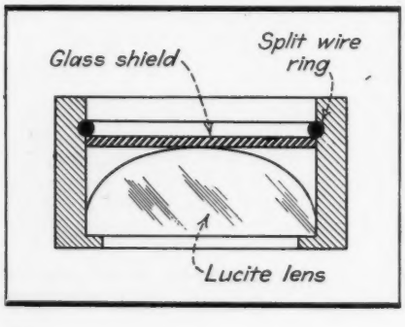
Instrument light case for Link trainer was formerly made of spun aluminum, with stamped steel clip to hold it in place. One zinc alloy die-casting now replaces two parts.

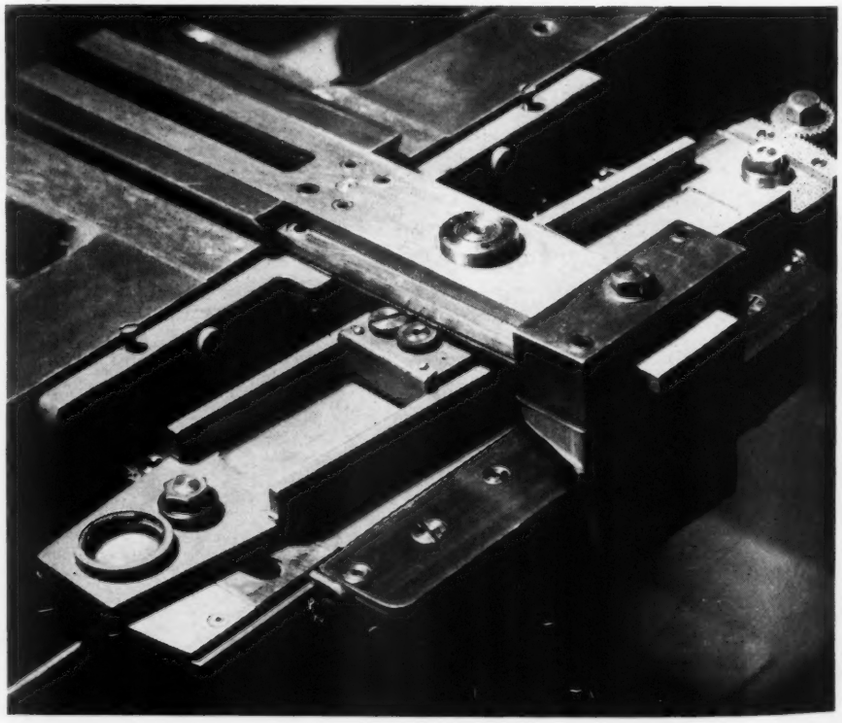


These four Link trainer parts also are changed from cast aluminum to zinc alloy die-castings. Die-castings are shown to right. More than 100 parts are now die-cast.

MAGNIFYING LENS ON LATHE IS MOLDED OF PLASTIC

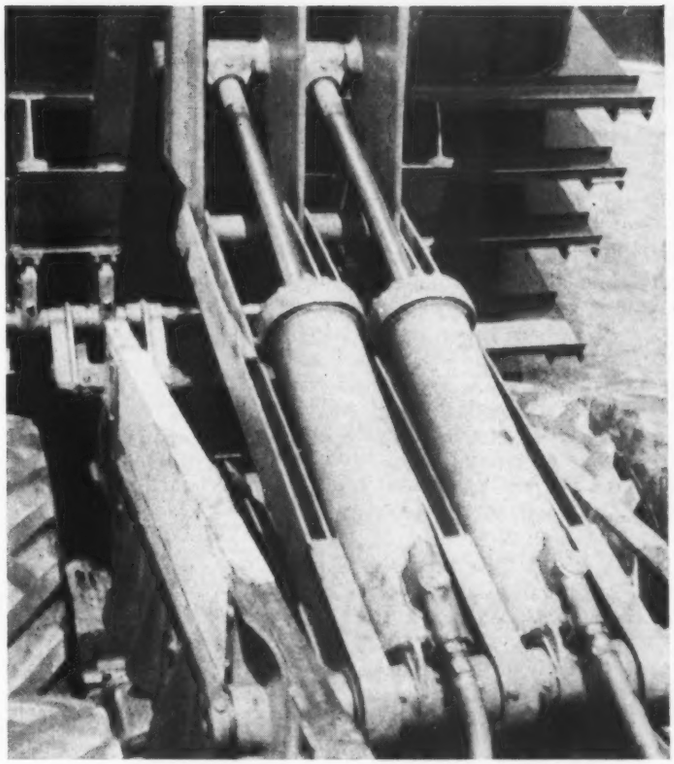
Magnifying lens molded from methyl methacrylate resin (Lucite) has been designed for the taper attachment of Monarch lathes to make graduations easier to read when cutting tapers to accuracies of 0.0001 in. The plastic lens is protected from scratching by a round glass shield. Both glass and plastics are held in place by a wire split ring in the mounting bushing. By molding the lens of plastic instead of making it of glass, production cost is reduced, lens breakage is eliminated, and hence replacements are reduced.



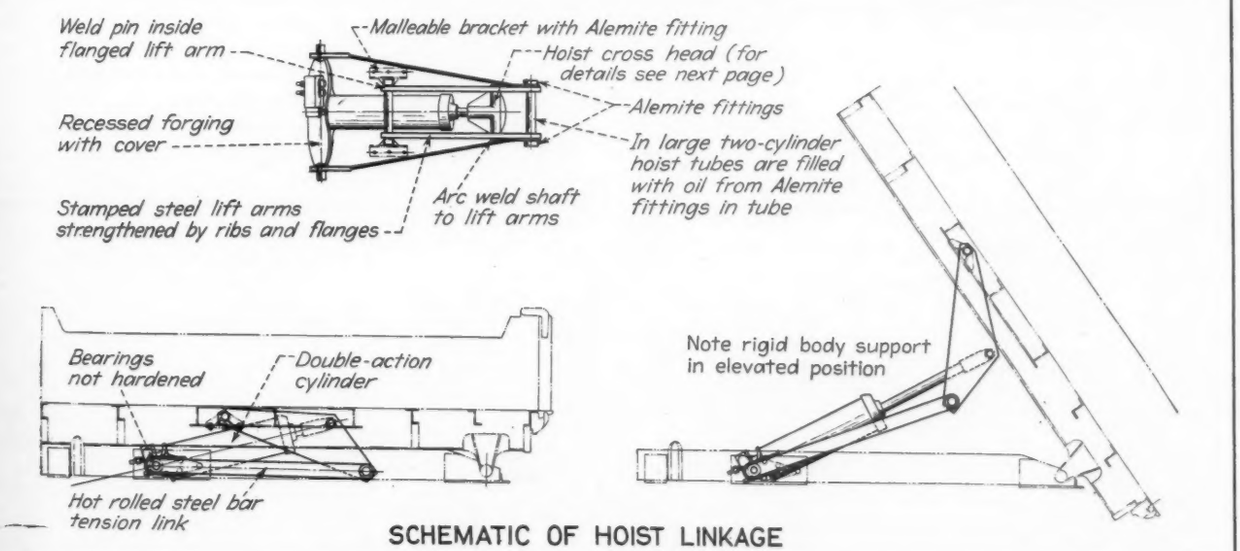


ARM TYPE HOIST PERMITS LIGHTER CONSTRUCTION

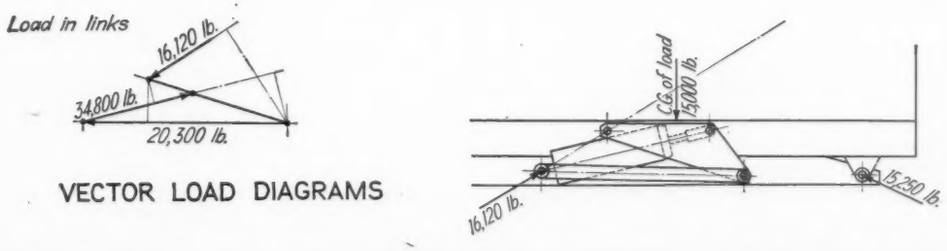
Practical limitations of mounting height, body weight, and oil pressure in hoists for high-performance dump trucks recently led to development by Gar Wood Industries of this linkage for an arm type hoist. Special consideration has been given to ruggedness and simplicity of design. Latest application is in big 2-cylinder hoist shown at right for giant trucks now in use on construction jobs in Panama.



Body is lifted at a point slightly ahead of the center of gravity, as shown in schematic drawing below, thus reducing bending moment and permitting lighter body frame construction. Reactions are more equally distributed into sub-frame, greatly reducing shear loads on body, hinge, hoist and trunnion brackets, and permitting lighter construction at these points. Hoist effort is reduced, with consequent reduction in oil pressure. The body accelerates when raising, and decelerates when lowering, thus reducing shock on the chassis frame. Vector load diagrams at bottom of page show load distribution of arm hoist. (*continued on next page*)


Weld pin inside flanged lift arm
Malleable bracket with Alemite fitting
Hoist cross head (for details see next page)
Alemite fittings
Recessed forging with cover
In large two-cylinder hoist tubes are filled with oil from Alemite fittings in tube
Stamped steel lift arms strengthened by ribs and flanges
Arc weld shaft to lift arms
Bearings not hardened
Double-action cylinder
Note rigid body support in elevated position
Hot rolled steel bar tension link

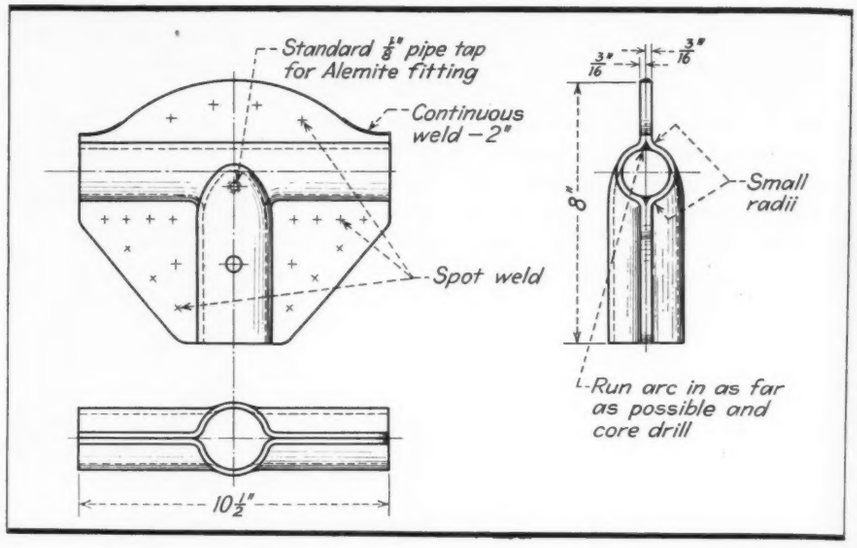
SCHEMATIC OF HOIST LINKAGE



VECTOR LOAD DIAGRAMS

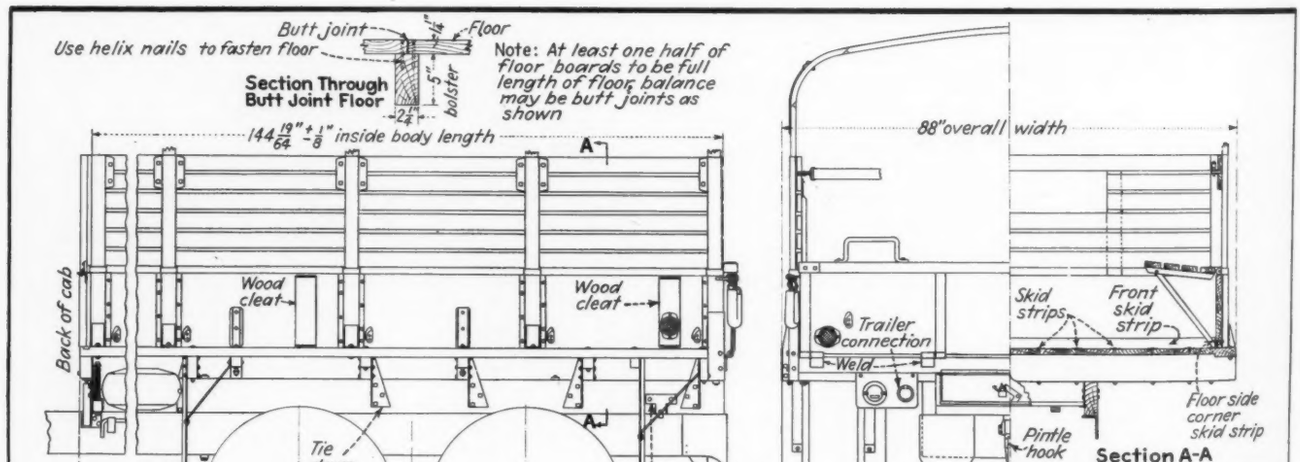
ARM TYPE HOIST (continued)

Steel stampings are used wherever possible in the Gar Wood arm type hoist. Crosshead for smaller hoists, shown at right, is made from two identical $\frac{3}{16}$-in. thick mild steel stampings securely spot-welded together. Arc welds strengthen the crosshead at hole for pin. Webs on crosshead transfer load from piston rod evenly throughout cross pin; otherwise full cylinder thrust would be concentrated on center of pin, causing it to deflect and wear unevenly. Lifting arms (not shown) are stamped from 7-ga. mild steel, and are ribbed and flanged. For added strength, a $\frac{3}{16}$x 1x1½-in. angle section is spot-welded along the lower flange of the lift arm. Tension links are simple hot rolled steel bars. All bearings are grease-lubricated from Alemite fittings.



ARMY SWITCHES TO WOOD FOR CARGO TRUCK BODIES

Steel formerly used in panels, floor, understructure and tailgate of Army cargo truck bodies is now replaced by wood, with a saving of approximately 1,000 lb. of steel per body. Five sizes of bodies have been changed, but the **144x80-in. body shown below for 2½-ton** truck accounts for about 80 percent of the number being produced. Wood bodies are of the same size and capacity as steel bodies. Tarpaulins, bows, seats and lazybacks are interchangeable between wood and steel bodies. To permit use of available lumber supply, half the floor boards and all the lower lazyback boards may be made of more than two pieces of lumber, each shorter than 12 ft., with a half-lap splice. Also, boards 2 in. thick or thicker, with exception of beech, yellow, birch and hickory, may be laminated from 4/4 or 5/4-in. boards, using non-extended urea laminated glue. Use of 4/4-in. lumber this way will save much time in kiln-drying. Kiln schedule for oak lumber in drying from 18-22 percent moisture down to 8 percent moisture is 10 days for 4/4 lumber; for 8/4-in. lumber it is 60 days. Lumber for truck bodies must have moisture content of 10-16 percent (measured 7 days after removal from kiln), and must be of good grain with rounded corners and smooth finish to prevent splintering. Wood is sealed with toxic sealer, primed with refinishing primer and finished with Army lusterless paint. Wood species permissible are indicated on the drawing. Metal parts are interchangeable, are treated with chemical rust-resistant finishes before painting, and are preferably assembled by bolts with washers.



SPECIES OF WOOD	OAK	ASH	BIRCH MAPLE	BEECH	YELLOW BIRCH	HICKORY	PECAN	DOUG AS FIR	DMKS SO PINE	ROCK ELM	WEST LARCH	BLACK LOCUST	N WHITE PINE	SUGAR PINE	LONG LEAF YELLOW PINE	YEL POPLAR	CYPRESS	BLUE GUM WOOD	BLACK WALNUT	POND PINE SA
SILLS AND BOLSTERS	✓	✓	✓	✓	✓	✓	✓			✓		✓								
PANELS	✓	✓	✓	✓	✓	✓	✓	✓					✓	✓	✓	✓	✓	✓	✓	✓
FLOORING	✓	✓	✓	✓	✓	✓	✓	✓		✓		✓								
TROOP SEATS LAZY BACKS RUB RAILS STAKES, BOWS	✓	✓	✓	✓	✓	✓	✓													
TAILGATE	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓								

WARTIME DEVELOPMENTS

The growing wood shortage has the War Production Board bobbing around like a slack-wire artist these days.

Faced with shortages in several metals, notably steel for non-fighting equipment, the Board has been substituting hardwood wherever possible, but now, confronted with a lumber shortage estimated at 6,000,000,000 board-feet for essential use alone, the agency is forced to substitute for wood wherever possible. As a result, wood is getting to be the substitute for which you must substitute.

The Army, Navy and Maritime Commission have designated the Engineer Corps' construction division as central procurement agency for all their lumber. Other federal agencies may join in this purchasing pool which is expected to result in more efficient distribution, lower costs and increased production.

Under this system, the construction division will be purchasing well over half the lumber production of the country and about 85 percent of the supply of those grades sought by the Army, Navy and Maritime Commission.

A quick idea of the size of the job may be obtained from these figures: From September 1940, to August 1942, the Engineers bought 6,037,019,427 board feet of lumber. Now they expect to purchase that much in the next four months.

With a permanent distribution-control system in the offing, the WPB named Ben Alexander, of Lake Forest, Ill., president of Chicago's Masonite Corporation, to work with all WPB agencies involved, as well as the armed forces, the Maritime Commission, the Office of Price Administration and other government agencies.

To save steel, the WPB decreed that hardwood must be used wherever possible in transportation services. Truck and railroad car bodies are two categories in which the order can help.

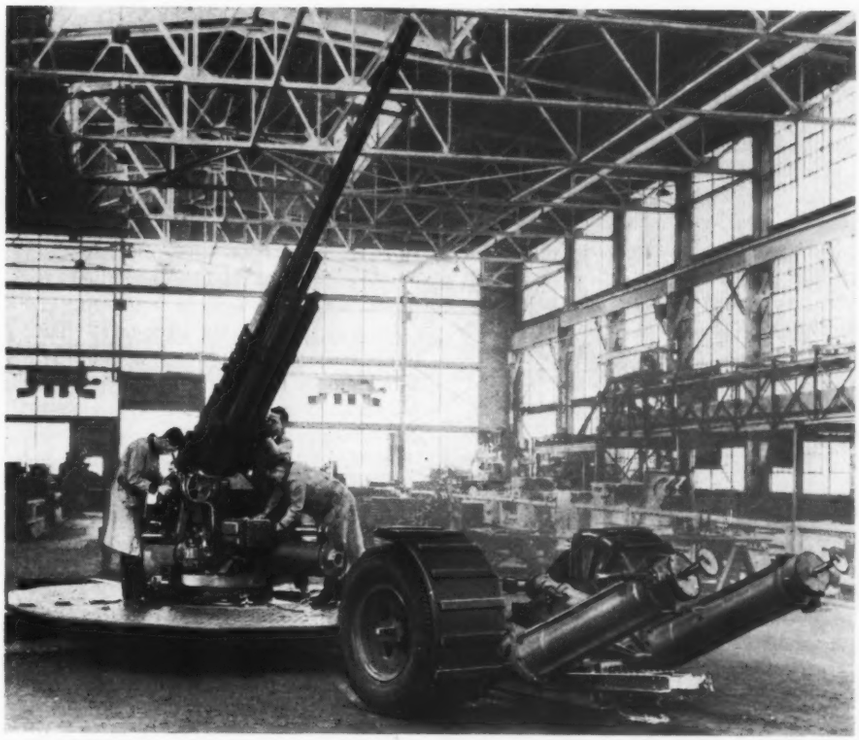
White oak, urgently needed in ship construction, may no longer be used for manufacture of veneer except for implements of war to be delivered to the armed forces, the Maritime Commission or the War Shipping Administration. Implements of war include aircraft, ammunition, armament and weapons, ships, tanks and vehicles. Stocks totalling more than 50,000 b. ft. are frozen.

On the heels of this restriction came an order freezing all Noble fir and western hemlock aircraft logs in the hands of their owners as of September 11. No processing of the frozen supply is allowed except on authorization of the WPB's Director General for Operations.

At the same time, WPB called on manufacturers of wood furniture to take over as largely as possible the manufacture of many civilian products customarily made of metal. The WPB's furniture branch pointed out that a steady flow of wood lockers, shelving, ice boxes, wash tubs, pails, pumps, conveyors, track, lamps and trailers would help alleviate many shortages which will be catching up with civilians when present stocks are exhausted. The furniture men do not by any means get a free rein, however, for in the same breath, the WPB warned them that high common grades, structural timbers of softwood, and No. 1 common and better grades of hardwood must be preserved for war purposes. The furniture makers must supply civilians from the lowest grades which will yield cuttings of suitable size and quality.

At the other end of the line, the army and navy ordered shippers to substitute fibre containers for wood and metal wherever practical. New fibre boxes are made of waste paper, are weather proof, save space and weigh two pounds less than equivalent wooden boxes. The services issued their orders at the request of the WPB's Conservation division.

At least two important exceptions to the broad Production Requirements Plan have been announced by the War Production Board. One of these will allow companies operating under the



While United States aircraft factories continue their feverish production to put a ceiling of planes over the Axis, our anti-aircraft defense program is not standing still. Shown here is a relatively new gun which is similar to although more powerful than those which made a shambles of the Japanese attempt to bomb Corregidor into submission. This improved gun can reach almost seven miles into the air to wipe out a bomber. It is mobile, hurls an explosive shell and may be fired by remote control. A weapon similar to this has been "unusually successful" against raids over England. This gun is at least five months ahead of schedule in Fisher Body plants, where finished guns were being turned out four months after contracts were let. The first guns were not expected by the Army until fall. Automotive techniques helped speed production.

plan to purchase greater amounts of certain commodities than are authorized by their certificates. The other will allow companies which have applied for but not received their PRP certificates to accept delivery of stipulated amounts of the materials called for by their certificates.

Exemption No. 2 allows purchase of any material not included on Materials List No. 1 of the fourth quarter PD-25A application form or of any material exempted from inventory restrictions by General Inventory Order M-161. This applies even though such acceptance is in excess of the amount authorized on the company's PRP certificate. It affects chemicals principally, since these were omitted from the fourth-quarter materials list. Other exempted materials include some for manufacture of refractory brick, and waste paper, bulk salt, borax, caustic soda and soda ash.

Under the extended interim procedure for applicants whose PRP certificates have not been issued, Class 1 producers, or companies which use more than $5,000 worth of metal in a quarter and which are required under Priority Regulation No. 11 to obtain priority assistance under the PRP, may accept delivery of as much as 70 percent of their indicated requirements for any quarter during its first and second months if they have submitted the required PRP application and have not received their certificates.

Ratings on orders received by them may be extended or applied to obtain necessary material. Companies also may use ratings under any "P" order under which they have previously operated even though the order may have expired.

Class 1 producers who have submitted their PRP applications for the fourth quarter but who have not received cerficates may order up to 40 percent of their indicated requirements for delivery in October, and up to 70 percent of those requirements for delivery in October and November.

All third and fourth quarter deliveries made under the new procedure, however, must be deducted from the amounts authorized on PRP certificates when they are issued, and all such deliveries are subject to all other WPB orders.

The War Production Board's Copper branch has released an "order blank," form PD-595, to facilitate purchase of copper or copper-base alloys by manufacturers holding A-1-i or higher preference ratings. The Copper branch owns no metal but maintains detailed inventories of these materials in frozen, idle or excess stocks, by means of which it puts purchasers in touch with owners. Inventory lists are prepared twice weekly and may be seen at any WPB field office or at offices of the Copper Recovery Corporation, 200 Madison Avenue, New York, N. Y. Manufacturers have been urged to request those supplies they need without inspecting the lists if a shut-down because of material shortage threatens their operations.

Engineers at the Glenn L. Martin aircraft plant have devised a simple way to beat a long-standing weakness in the use of sheet aluminum for aircraft surfacing—wrinkling and buckling of the aluminum skin under pounding of riveting guns.

The new "heat therapy" system involves riveting the sheets together on a wooden frame that has the shape of the wing. Then, wrinkled and buckled, the skin is laid on the wing spars. The skin heater fits snugly over it, and a few minutes after the heat is turned on, the aluminum sheet has been raised to a temperature of 140 deg. F. While rheostats hold the temperature constant, the skin is stitch-riveted along the ribs and around the edges. Then the heater comes off, and as the skin cools, it shrinks, taut and unwrinkled.

The device was developed by Harry F. Kniesche, assistant factory manager, after lengthy experiment and research. Not only does the process remove wrinkles which had an adverse effect on plane performance, but, in allowing the assembly of the entire skin at one time, it has speeded production. Scores of such work speeders are reported monthly.

Just how successful America's inventors have been in providing new equipment for the armed forces is a military secret, but the National Inventors' Council reports that its results thus far have been considerably better than had been expected.

The council was set up under the Commerce Department two years ago to pass on ideas of the nation's mechanically-minded citizens. It expected to harvest one useful idea out of every thousand suggested. Thus far, about five percent of all proposals have been termed "decidedly interesting," although not all of them have been accepted. Since its organization, the council has received about 95,000 ideas, and 300 to 400 more are received daily.

Directors of industrial research and laboratory or trade association chiefs are urged to study all discoveries from the viewpoint of their military value and to submit those they consider worthwhile to the council.

The War and Navy Departments have approved a molybdenum steel which contains neither nickel nor chromium to replace S.A.E. 2330 nickel steel in manufacture of bolts, terminals, clevises, pins and various other aircraft parts. Specification AN-S-9, which covers this steel, has been issued and will become effective not later than November 5.

The newly-approved steel, numbered 4037, contains 0.035 to 0.040 carbon and 0.20 to 0.30 molybdenum. Its principal contrasts with other S.A.E. molybdenum steels are its silicon (0.20 to 0.35 percent) managanese, (0.75 to 1.00) and sulphur, (0.040 max.) contents. Phosphorus content of 0.040 corresponds to other S.A.E. moly steels.

The steel must be of aircraft quality and satisfactory for fabrication of parts which must meet magnetic inspection. Copies of this specification may be obtained from the Bureau of Aeronautics,

Navy Department, Washington, or from Material Center, Army Air Forces, Wright Field, Dayton, Ohio.

The following physical properties are specified for material quenched in oil from a temperature of 1,525 to 1,575 deg. F., and tempered at 950 deg. F. minimum:

Minimum Tensile Strength (lb. per sq. in.)	125,000
Minimum Yield Strength at 0.2 percent set or at extension indicated (lb. per sq. in.)	100,000
(Extension under load in 2 in.)	0.0107
Minimum elongation in 2 in (percent)	17
Minimum reduction of area (percent)	50
Maximum hardness (Brinnell)	229
(Rockwell)	C - 21

Designers should exercise the greatest possible care in specifying metals to insure that they do not call for critical materials when substitutes will do the job, according to the War Production Board's Conservation division.

As an example, the Conservation division cited three bronze alloys which indicate the spread in metal requirements. Navy gun metal, or Composition G, composed of 88 percent copper, 10 percent tin and two percent zinc, requires primary copper or No. 1 scrap, and primary tin. Composition M, 88 percent copper, 6½ percent tin, 1½ percent lead and 4 percent zinc, can be made up largely of secondary metal. Ounce metal, 85 percent copper and five percent each of tin, lead and zinc, can be made entirely of scrap, or secondary metal. The latter two alloys can be substituted for Composition G in many instances, saving considerable supplies of new metal.

Defense Supplies Corporation became sole purchaser of all imported raw jute last September 1, by War Production Board order.

A midwestern producer of alloy steels has developed a method of meeting all customer-requirements for tungsten steel fairly.

Based on the fact that orders for this product fall into a limited number of shapes and sizes, the company formed a pool of all such metal it produces, and fills orders from that pool. In this way, occasional heat failures do not hold up the customer whose order was to come from the ruined heat, and the company keeps on producing full time, without particular regard for which customer gets what steel. The plan gets shipments out on schedule and keeps everyone happy except the accountants and bookkeepers who have to match up shipments and orders.

Shipping bound for the United States has become tight enough for strict priority control, and a list of 500 vital items to which ship space will be assigned has been drawn up. Only exception on vessels controlled by the War Shipping Administration will be lower-rated cargoes from the Carribean area, U. S. insular and territorial possessions, the British Isles, Canada and Newfoundland which may have what space is not needed for emergency items.

Balsa wood stocks totalling more than 100 board feet have been frozen, and hereafter may be used only for specific types of life saving, aircraft or technical apparatus bound for government agencies or lend-lease shipment.

Lead production is ahead of demand, and the order creating the monthly lead pool of 15 percent of each producer's output, set aside for allocation by the War Production Board, has been revoked.

The War Production Board has banned further use of copper or its alloys for fuse parts other than those which carry current. Assembly of fuses in which copper or its alloys is used for parts other than those bearing current also has been banned, and sales of fuses by manufacturers is restricted to holders of preference ratings of A-10 or higher. The first and third orders took effect September 8, the second September 23.

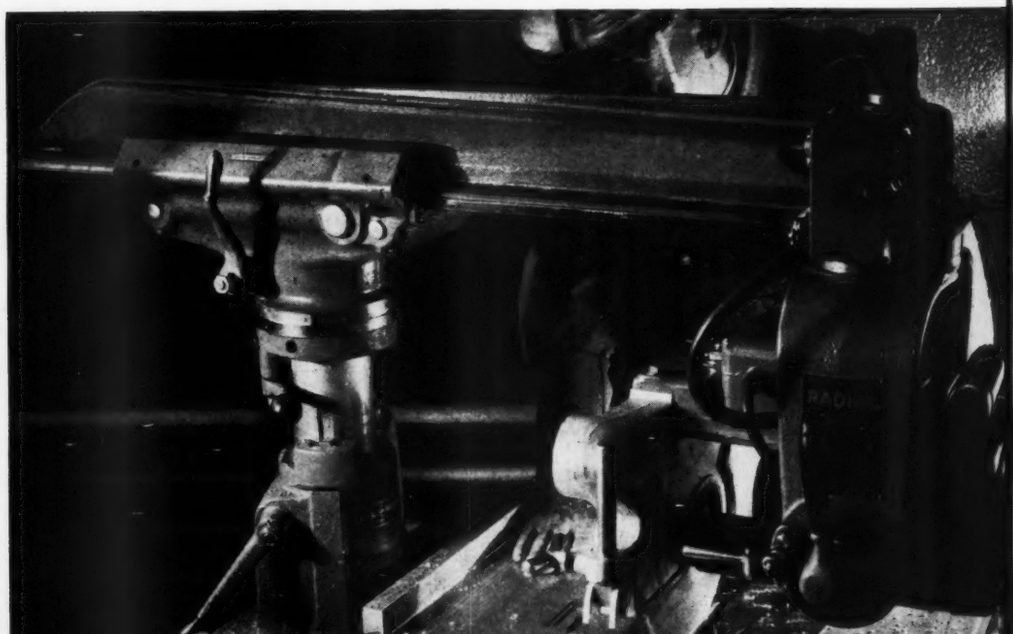
Bakelite Corporation

Extrusion machine molding is playing an important part in wartime production

Choice

AIRCRAFT PARTS FOR WHICH PLASTICS SHOULD BE CONSIDERED

- Blisters
- Bushings
- Cable guards
- Cable stops
- Canopies
- Conduit
- Doors
  - Baggage
  - Bomb
  - Cabin
  - Emergency exit
  - Inspection
  - Landing gear
- Ducts
- Fairings
- Fairleads
- Fittings
  - Armament
  - Control
  - Equipment
  - Hydraulic
  - Tubing
- Flooring
- Furnishings
- Fuse boxes
- Handles
- Idler horns
- Instrument panels
- Interior furnishings
- Junction boxes
- Knobs
- Propeller spinners
- Reflectors
- Scoops
- Shell chutes
- Silent gears
- Surface tabs
- Tab drums
- Tail cones
- Tanks
- Terminal blocks
- Tuning
- Wing leading edges
- Wing tips



Du Pont

Table, pull type and radial circular saws similar to those used for cutting wood or metal are suitable for cutting Lucite methyl methacrylate resin

of Plastic Materials As Affected By Fabrication

HORACE C. HILLMAN
Production Engineer, Lockheed Aircraft Corporation

In selecting a plastic material best suited to the desired design of a given part there are three general considerations in addition to the physical and chemical characteristics of the materials, which have an important bearing upon the choice. These are the physical forms of the raw materials that are commercially available, the comparative advantages of the various methods of producing either a finished or unfinished part from these raw materials, and the fabricating operations which may be necessary on an unfinished part of the solid raw materials. These considerations complement design kinks and properties on pages 498-501 and 545-6 of September *Product Engineering*.

FOUR general forms of the raw plastic materials are employed in various fabricating processes. These are liquid, powder, solid, and laminated. Liquid "casting plastics" are available in unfilled phenol formaldehyde, acrylate and polystyrene. All plastic materials are available in powder form for molding, extruding, and special applications. The solid materials are those which have already been cast in standard shapes and sizes, such as in sheets, tubes, bars and rods. Solid plastic is also available in many extruded sections.

Laminated plastic is in solid form such as sheets, rods, and tubes with sheet fillers of paper, linen, canvas, or spun glass. Phenol-formaldehyde and urea-formaldehyde plastics are used for this purpose. Sheets of impact-resistant filler coated with these materials are available for blanking and laminating. Sheets of cellulose acetate or polyvinyl compounds are also available for blanking and laminating. Plywoods, even when plastic bonded and impregnated, are not considered plastics.

Fillers

Fillers consisting of wood flour, minerals, fibres or macerated fabric are often used in plastics, particularly thermosetting plastics, to impart special properties such as strength, light weight, cost economy, or appearance. Properties of plastics are governed more by the type and amount of filler than any other one item.

An important consideration in using filler plastics is that as soon as the plastic is machined, the filler material is exposed. Properties such as water absorption, fire-resistance, dielectric strength, notch sensitivity and others are affected accordingly.

Woodflour and similar fillers are used to create bulk, lower specific gravity, and decrease cost. Plastics containing these fillers flow easily in the mold, machine freely, and do not settle out of a casting resin.

Mineral fillers are used to increase heat and electrical resistance, produce hardness, improve anti-friction properties (graphite) and, in some instances, to increase compressive strength. They often make die abrasion great but still flow easily in the mold. Machining is often poor and extremely large granule sizes settle out of casting resins.

Fibres are used to increase flexural, impact, shear, and other strengths. Fibres retard mold flow greatly so that high molding pressures are required. They also tend to settle out. Fibre-filled plastic machines fairly well.

Shock resistance and flexural strength are increased by the addition of macerated fabric or cordage. However, these fillers also greatly retard mold flow and do not mix well into casting resins because they hinder escape of air bubbles. The resulting plastic material machines fairly well.

Fabrication Processes

Plastic articles are usually produced by three general methods: molding, casting, and extrusion processes. Molding processes are classified as compression molding, injection molding, and special process molding.

Compression molding of plastics is comparable to the press-forging of metals. The heat and pressure which force the material to take the form of the die cavity are applied by the dies themselves. Thermoplastic materials are seldom compression molded because an added cooling operation would increase tooling costs and curing cycle.

The advantages of compression molding are (1) the ability to make larger parts, (2) stronger parts, since high strength fillers can be used, (3) thicker parts, and (4) more variegated color striation (less unit flow).

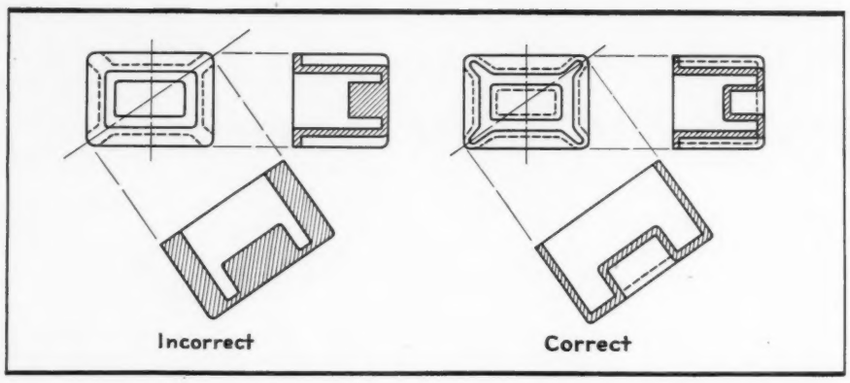
Designs that create excessive mold loads, such as those requiring long wedge-shaped plungers and thin mold projections transverse to material flow direction, should be avoided since molding pressures are caused by and are coincident with mold closure movement.

Injection molding of plastics is comparable to the die-casting of metals. Heated material is forced through an orifice into the closed cavity. For this reason fillers must be held to low percentages and small elements.

The advantages of injection molding are fast production, less finishing, uniform parts, less material waste, less core support required, and ability to make long thin parts. Uniform wall thickness of parts is highly desirable to assure uniform cooling.

Transfer molding is a name applied when thermosetting materials are injection molded. It requires more complex heating and control, and, therefore, it is used only when its advantages over compression molding offset these drawbacks. The advantages obtained by using transfer molding instead of compression molding are closer tolerances, injection molding flow conditions, larger and/or more intricate inserts, molded threads across the parting plane, and abrupt changes in section.

Special process molding is required when plastics contain high-strength fillers because of the excessive pressure required to obtain flow in the mold. Pre-forming of the material to conform to the mold contour obviates flow within



Uniform wall thickness assures uniform cooling of plastic pieces

the mold, permitting much larger parts.

In the most outstanding of present pre-forming methods, a contoured screen is lowered into a suspended solution of resin-coated fibres. By exhausting air from the top side of the screen, a contoured mat of uniform thickness is obtained. By this method, parts containing as high as 70 percent filler may be molded with as low as 50 lb. per sq.in. pressure. Three limitations of the process are that the fibres are not aligned with respect to each other, only parts of fairly constant thickness can be made, and the total curvature should not exceed 60 deg. per part.

Casting Methods

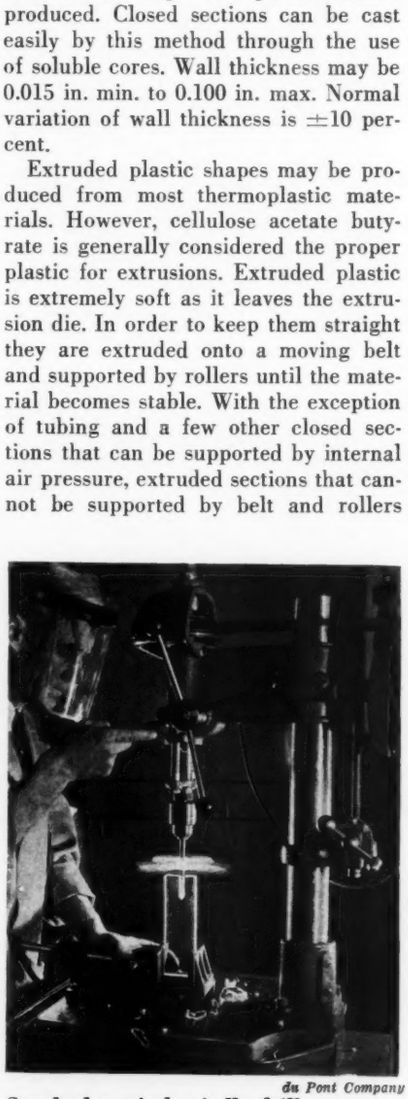
Casting methods are generally poor means of production for large quantities of parts. However, plastics may be cast economically in quantities from 50 to 1,000. Plastics may be cast from liquid materials only since, unlike metals, neither solid nor powdered plastics will became liquid by application of heat alone.

There are no size limitations on castings such as press capacities and high mold loads place on molded parts. Filler and coloring materials may be added as desired. This is possible only in casting. In all other forms of plastics, it is done by the material manufacturers and may not be altered. Fibre inserts may be used in castings since temperature of 150 deg. F. need never be exceeded.

In mold, slush, and centrifugal casting of plastics the same general design considerations apply as in casting metals by these methods. Minimum web thicknesses vary from 0.05 in. min. for unfilled materials to 0.10 in. min. (average) for filled materials. "Tolerance" and "draft" requirements are the same as for compression molding except for slush casting where tolerances cannot be applied to wall thickness. Weight tolerances should be shown on all drawings for the slush cast parts.

Dip casting is well suited to casting liquid plastic materials because of their high viscosity. Almost all thermoplastic materials can be dissolved in a solvent from which "dip" cast pieces can be produced. Closed sections can be cast easily by this method through the use of soluble cores. Wall thickness may be 0.015 in. min. to 0.100 in. max. Normal variation of wall thickness is ±10 percent.

Extruded plastic shapes may be produced from most thermoplastic materials. However, cellulose acetate butyrate is generally considered the proper plastic for extrusions. Extruded plastic is extremely soft as it leaves the extrusion die. In order to keep them straight they are extruded onto a moving belt and supported by rollers until the material becomes stable. With the exception of tubing and a few other closed sections that can be supported by internal air pressure, extruded sections that cannot be supported by belt and rollers should be avoided. Endless lengths may be extruded by means of the screw feed method. Symmetrical sections are preferred. Minimum tolerance is ±1.5 percent or ±0.005 in., whichever is greater. General tolerance is ±3 percent or ±0.005 in., whichever is greater.



du Pont Company

Standard vertical spindle drill presses of fixed or radial head type are satisfactory for methyl methacrylate resin

Laminated material has the physical properties of the filler (as retained by the binder) and the chemical properties of the plastic material whether it consists of sheets of plastic coated filled or alternate sheets of plastic material and filler material.

Fillers consisting of elements that are enmeshed minute fibres generally produce less tensile strength and more impact strength than fillers consisting of elements that are individual fibres. Fillers whose elements are aligned have more tensile strength in the direction of element alignment than in other directions. The direction of the grain must be indicated on drawings because laminated parts must be so designed that major stresses do not tend to delaminate the material nor separate aligned fibre elements.

Fabricating Operations

All machining methods used on metals and most of those used on woods may be employed on plastics. Although most unfilled plastics have machining qualities similar to good hardwood or soft metal, filled plastics are likely to be abrasive.

Designs for filled plastics should not require close machining of such nature that there is no means for compensating for tool wear. Reaming, tapping and like operations should be avoided in favor of such alternatives as boring and the use of inserts.

Shear type blanking operations may, in general, be used on plastic sheets up to 0.12 in. thick. Thermoplastic materials may, when heated, be sheared in thicknesses up to 0.30 in. However, this requires an additional operation and should be avoided if possible. Brittle materials shear with rough edges. Therefore, close fits usually require an additional operation.

Standard minimum machining tolerance is ±0.010 in. Where closer dimensions must be held, tolerances of ±0.002 in. in lathe work, ±0.004 in. in mill work, and ±0.001 in. by grinding are possible.

Since absorption of moisture, temperature variation, and "aging" all tend to give various amounts of dimensional instability to plastic materials, these effects should be checked before specifying close tolerances.

The only heat formable materials are thermoplastics. Sheets may be drawn or

formed at 200 or 300 deg. F. in much the same manner as sheet metal. Minimum bend radius is double the thickness. Thermoplastic sheets may also be hot formed to a female die by applying hydraulic or pneumatic pressure. This method may be used to form closed sections.

Assembly Methods and Finishes

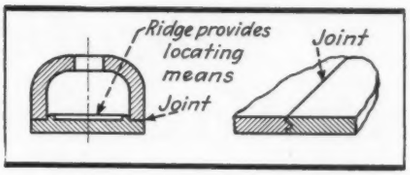
Plastic designs should incorporate their own attachment means wherever possible. In thermosetting and thermoplastic materials, this can be done by means of machined or molded threads, inserts, and other means. Advantage may also be taken of the hot forming properties of thermoplastic materials to provide permanent attachment.

Hollow or spun rivets may be used but driven rivets, squeezed rivets, or wedging assembly means, such as taper pins and the like should be avoided. Self-tapping screws, drive screws or serrated bushings may be used providing their installation does not impose excessive pounding loads or wedging pressures, and providing they are not subject to subsequent disassembly.

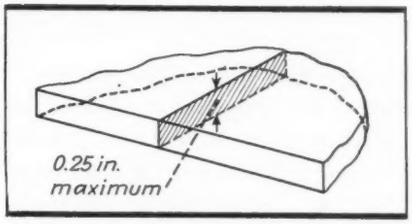
Use of cementing, solvent fusions and similar means is practical for permanent assembly if parts are specifically designed for such attachment from a production standpoint. This type of design should not be used unless distinct advantages may be derived.

Thermosetting materials generally are not soluble and must be glued. This type of joint is only as strong as the adhesive used and the efficiency of its adhesion to the parts being joined. When glued or solvent fusion attachment is to be used, integral means for location of parts must be provided. To allow for escape of solvent or drying of glue, no point to which glue or solvent is applied should be imbedded more than ⅛ inch.

Thermoplastic materials are soluble and may be fused with the aid of a solvent. Joint efficiency of 65 percent is developed when the joint is oven cured, approximately 45 percent when air dried. In filled materials and those having oriented molecules due to extrusion, stretching, and similar operations, joint properties are lower because efficiency pertains to the basic material only.



Integral means for locating parts to be attached to each other must be provided



No point to which glue or solvent is applied should be imbedded more than ⅛ inch. Total thickness here may be 0.25 inch

Surface finish of molded plastic parts is identical to that of the mold and can be buff, satin, or other degree of smoothness as desired. Machine finishes of any grade may be produced also. Although most materials may be buffed to a high gloss this should not be attempted with materials that contain fillers.

Coatings such as paint, varnish, lacquer and others may be applied directly to thermosetting materials. However, some of the thermoplastic materials require special protection against the chemicals in paints, which means added operations and expense. Parts requiring these finishes should, therefore, be made of thermosetting materials.

Internal bosses or webs placed in the center of flat surfaces will show on the outside as darker or opaque areas. On thin and transulscent materials, the darkness or lightness of an underneath material may require the color of the plastic to be different than the desired resultant color of the assembly. Since it is undesirable to use a darker color than necessary, inserts or underneath articles can be painted to harmonize or neutralize their color-changing effect. Large flat surfaces may be engraved or embossed to hide small irregularities resulting from a shrinkage or other cause. This is often a costly procedure and is not often done.

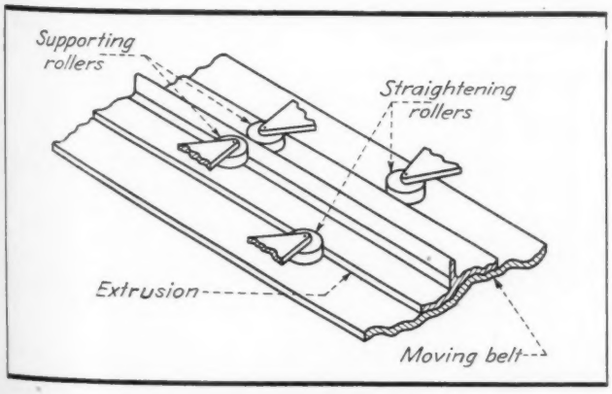
Metal plating may be applied to all plastic materials for decorative purposes, improvement of electrical conductivity or shielding properties, reflecting or opaque properties, or for other reasons.

Special Materials

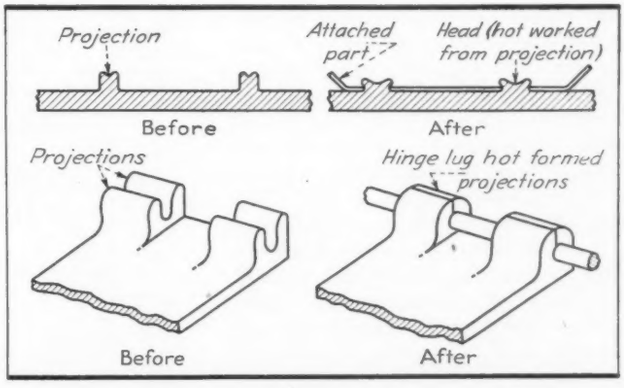
High tensile materials such as Nylon and Saran have tensile strengths as high as 80,000 lb. per sq.in. in a given direction. Typical applications are for woven seat covers and furniture. Advantages include extreme flexural toughness, lack of moisture absorption, smooth surface, wear resistance and choice of color.

Various plastic films are available that will resist all materials except concentrated nitric acid or the turpine oils found in citrus rinds. Applications include water vapor barriers to prevent condensation between inner and outer windows of pressurized airplane cabins, linings for tanks made of wood or other porous materials so that they will retain liquids, and seal strips for skin lap joints.

Heat dispersing surfaces may be produced by laminating a layer of brass or aluminum mesh (fine screen or perforated foil) below plastic surfaces.



Extruded plastic is kept straight by rollers and moving belt, which support the material until it becomes stable



Hot forming properties of thermosplastics can be used to advantage in making permanent attachments with other materials

Calculation of Vibrations In Multi-Mass Systems

C. R. FREBERG
School of Mechanical Engineering of Purdue University

Method for the determination of linear and torsional vibrations produced in mechanical multi-mass systems by impressed vibratory forces or by initial displacements or shocks. This method is based on a concept of mobility, or ease of motion, and the use of complex numbers similar to those used in the solution of electrical circuits.

VIBRATION problems in which are involved a large number of masses and elastic members are always difficult to solve. Likewise in the design of systems that make use of damping elements complicated mathematical equations are usually encountered. One of the newer methods proposed for the solution of such problems is the mobility method developed by F. A. Firestone. ("The Mobility Method of Computing Vibration of Linear Mechanical and Acoustical Systems; Mechanical-Electrical Analogies," *Journal of Applied Physics*, Vol. 9, June, 1938, p. 373, and "Vibration and Sound.") This conception of mobility or ease of motion seems to have definite advantages in some types of problems.

The mobility theory is similar to the electrical circuit theory except that the elements are mechanical. The method can be readily understood by following through the steps involved in its use. First, a diagram is made to represent the mechanical elements in the system. The symbols used in this article to represent the elements are listed in Table I. Second, the velocity is taken across the elements and the force is taken through the elements. The velocity across an element is the velocity of one end relative to the other end. In this way the individual elements are independent of the rest of the system. Third, complex numbers are used to represent quantities such as velocity and forces which are assumed to be simple harmonic. Fourth, the mobility corresponds to the impedance in an electrical circuit. The mobility is defined as the ratio of velocity across the element to the force through the element, that is, it is the velocity produced by a unit force.

Three mechanical elements are considered: springs, friction or resistors, and masses. In a spring the displacement across it is proportional to the force through it. In a resistor, the velocity across it is proportional to the force through it. For a mass, the acceleration across it is proportional to the force through it. The effect of each element may be set up in terms of quantities used in ordinary vibration work. The compliance of a spring as used in the mobility method is the displacement per unit force and may be represented by $1/k$. The responsiveness of a resistor represents the velocity produced by a unit force and is represented by $1/r$. The mass of the mass, which is represented by m, is the force produced by a unit acceleration.

Most vibrations are simple harmonic so that a simple harmonic force produces simple harmonic displacements, velocities, and accelerations. Using complex numbers, the quantities or terms in Table II represent the harmonic quantities.

In dealing with complex equations multiplying by ϵ^{jwt} makes the respective vectors rotate at an angular speed w. Then the instantaneous values depend on the location of the vector at time t. Again a vector when multiplied by j is advanced 90 deg. so that the acceleration leads the displacement by 180 deg. and the velocity leads the displacement by 90 degrees.

Table I—Explanation of Symbols

Symbols	Quantity	Units
x	Displacement	in.
v	Velocity	in./sec.
a	Acceleration	in./sec./sec.
F	Force	lb.
z	Mobility $= v/F$	in./sec./lb.
k	Spring modulus	lb./in.
r	Damping constant	lb. sec./in.
m	Mass	lb. sec.^{2}/in.
t	Time	sec.
w	Circular speed	rad./sec.
ϵ	2.7183	
j	$\sqrt{-1}$	
	Ground	
	Harmonic force	
	Spring	
	Resistor	
	Mass	

The mobility z of an element, or a group of several elements, is defined as the ratio of the velocity amplitude across the element to the force amplitude through the element.

$$z = \frac{v}{F} \text{ in. per sec. per lb.}$$

Therefore, the mobility is a complex number; the absolute value $|z|$ is the ease of motion (the velocity produced by unit force) and its angle is the angle by which the velocity leads the force. The real part of the mobility is known as responsiveness and the imaginary part as the excitability. Energy is used up when responsiveness is present, but changes from kinetic to potential energy and vice versa when excitability is present.

Once the various constants for the elements are determined, the mobility is easy to calculate. In springs where

$$x = F/k$$

$$v = jwx = \frac{jwF}{k}$$

the mobility can be found from

$$z = \frac{v}{F} = \frac{jwF}{kF} = \frac{jw}{k}$$

This indicates pure excitability for the energy oscillates back and forth first as potential energy in the spring and then kinetic energy in the mass.

In the case of a resistor where

$$v = \frac{F}{r}$$

the mobility can be found from

$$z = \frac{v}{F} = \frac{F}{rF} = \frac{1}{r}$$

This is real so heat is dissipated as one would expect from a resistor.

For the mass where

$$F = ma$$

$$a = jwv$$

$$v = \frac{a}{jw} = \frac{F}{mjw}$$

the mobility can be found from

$$z = \frac{v}{F} = \frac{F}{jwmF} = \frac{1}{jwm} = \frac{-j}{wm}$$

These elements may be connected in parallel or in series depending on the specific problem. A connection is in series if the same force acts through the elements and the velocity across the elements is equal to the sum of the individual velocities. Likewise, a connection is in parallel when the velocity is constant across the elements and the force is equal to the sum of the individual forces. Therefore, the mobility of a series is

$$z = \frac{v}{F} = \frac{v_1}{F} + \frac{v_2}{F} + \frac{v_3}{F} + \ldots.$$
$$= z_1 + z_2 + z_3 \ldots.$$

and the mobility in a parallel connection is

$$z = \frac{v}{F} = \frac{v}{F_1 + F_2 + F_3 + \ldots.}$$
$$= \frac{1}{\frac{1}{z_1} + \frac{1}{z_2} + \frac{1}{z_3} + \ldots}$$

The actual mechanism or system must be represented by a schematic diagram to solve vibration problems. Consider the simple case of forced vibration with no damping as shown in Fig. 1(*A*) as an example. The schematic diagram must be drawn first. Those elements connected or referred to the fixed mass are represented by the usual electrical symbol for a ground. Masses are always referred to the frame since the mass has no relative velocity within itself but moves relative to the frame. As shown in Fig. 1(*B*) the vibrating force is inserted in the diagram at a point where it acts and usually on the extreme left side of the diagram.

When calculating the mobilities the general rule is to start at the right-hand side and calculate toward the impressed force. For the schematic shown in Fig. 1(*B*) the mobility at junction *a* is

$$z_a = \frac{1}{jwm}$$

the mobility at junction *c* is

$$z_c = \frac{jw}{k}$$

and the mobility at junction *b* is

$$z_b = \frac{1}{\frac{1}{z_a} + \frac{1}{z_c}} = \frac{1}{\frac{1}{1/jwm} + \frac{1}{jw/k}}$$
$$= \frac{1}{jwm + \frac{k}{jw}} = \frac{j}{\frac{k}{w} - mw}$$

When the force is known the velocity can be calculated from the definition of mobility

$$v_b = Fz_b$$

By referring to Table II for the relations between displacement, velocity and acceleration any other of these quantities can be calculated if one is known. This makes it simple to determine the motion of any part. Resonance curves can be drawn for a number of values of w and then the speed giving maximum amplitude can be determined. Another way of finding the resonant speed is to assume that it takes very little force to produce an infinite velocity or displacement. Then at resonance the force, or the denominator, should be zero, or

$$\frac{k}{w} - mw = 0$$

from which

$$w^2 = \frac{k}{m}, \text{ or } w = \sqrt{\frac{k}{m}}$$

This may be recognized as the expression for the natural frequency in radians per sec. which is also the speed for resonance.

A two mass system with damping, as shown in Fig. 2(*A*), will be used to illustrate the solution of a more complex system. In cases like this a general solution is often quite involved so that the solution with specific values often proves to be easier. In the system shown in Fig. 2(*A*)

k_1 = 20 lb. per in.
k_2 = 50 lb. per in.
r_1 = 2.5 lb. sec. per in.
r_2 = 1.25 lb. sec. per in.
m_1 = 19.3 lb. = 0.05 lb. sec.^{2} per in.
m_2 = 30.9 lb. = 0.08 lb. sec.^{2} per in.
F_o = 7 lb. at 1,760 r.p.m., or
w = 184 rad. per sec., applied to mass m_2

For a solution a schematic diagram must first be drawn. This diagram is shown in Fig. 2(*B*). The masses are acted upon by two springs (or a force and spring), the damping, and by the inertia which is relative to the ground. From this the mobilities of the various points can be calculated. Again the work must proceed toward the impressed force.

$$z_b = \frac{jw}{k_1} = \frac{j\,184}{20} = 9.2j$$

$$z_c = \frac{1}{r_1} = \frac{1}{2.5} = 0.4$$

$$z_d = \frac{-j}{wm_1} = \frac{-j}{184 \times 0.05} = -0.109\,j$$

Each of these three elements acts rela-

Table II—Expressions for Harmonic Quantities

	Instantaneous Value	Amplitude
Displacement	$x = x_o\,\epsilon^{jwt}$	x_o
Velocity	$v = dx/dt = v_o\,\epsilon^{jwt}$	$v_o = jwx_o$
Acceleration	$a = d^2x/dt^2 = a_o\,\epsilon^{jwt}$	$a_o = jwv_o = -w^2x_o$
Force	$F = F_o\,\epsilon^{jwt}$	F_o

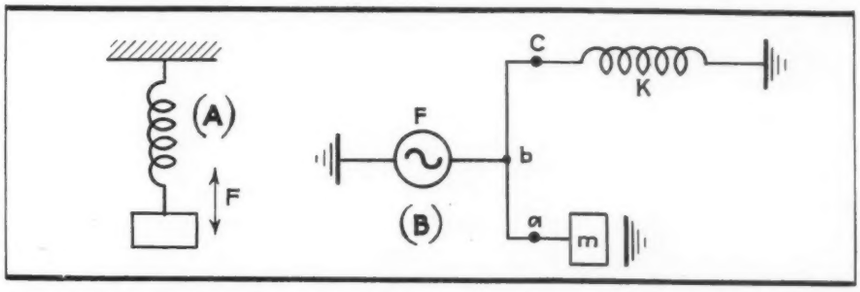


Fig. 1—(A) Simple system of forced vibration with no damping. (B) Schematic diagram for the simple system

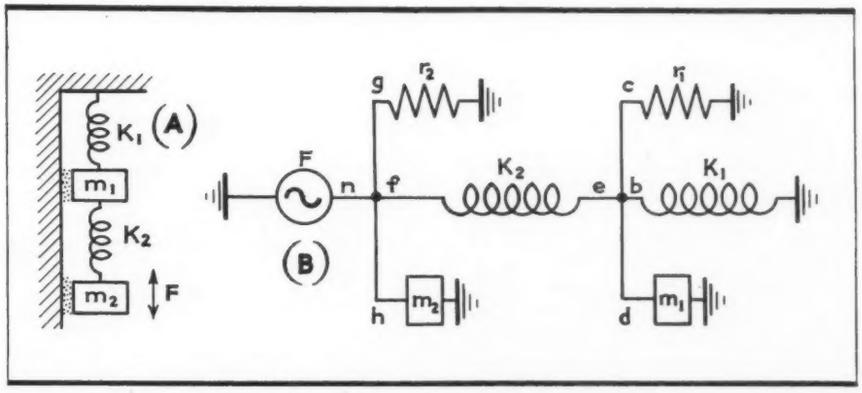


Fig. 2—(A) Two mass system with damping. (B) Schematic diagram for the compound or two mass system

tive to the ground so the mobility of point e is

$$z_e = \frac{1}{\frac{1}{9.2j} + \frac{1}{0.4} + \frac{1}{-0.109j}}$$

$$= \frac{j(2.5j + 9.0712)}{(2.5j - 9.0712)(2.5j + 9.0712)}$$

$$= \frac{9.0712j - 2.5}{(2.5\sqrt{-1})^2 - (9.0712)^2}$$

$$= 0.0281 - 0.1022j$$

$$z_{fe} = \frac{jw}{k^2} = \frac{184}{50}j = 3.68j$$

$$z_f = z_{fe} + z_e = 3.68j - 0.1022j + 0.0281$$

$$= 3.58j + 0.0281$$

$$z_d = \frac{1}{r_2} = \frac{1}{1.25} = 0.8$$

$$z_b = \frac{-j}{wm_2} = \frac{-j}{184 \times 0.08} = 0.068j$$

$$z_a = \frac{1}{\frac{1}{0.0281 + 3.58j} + \frac{1}{0.8} + \frac{1}{-0.068j}}$$

$$= 0.006 - 0.069j$$

When the mobility is known, the velocity can be calculated.

$$v_a = z_a F_e = (0.006 - 0.069j) \times 7$$

$$= 0.042 - 0.483j$$

$$= 0.484 < -85 \text{ deg.}$$

This indicates that the maximum velocity of mass 2 is 0.484 in. per sec. and that the velocity lags the force by 85 degrees.

This analysis may be carried back through the system and the motion of all other parts may be determined.

$$v_f = v_a$$

$$F_f = \frac{v_f}{z_f}$$

$$= \frac{0.042 - 0.484j}{0.0281 + 3.58j} = -0.135 - 0.0128j$$

$$= 0.136 < -174.7 \text{ deg.}$$

The amplitude of the force at f then equals 0.136 lb. and lags the impressed force by 174.7 degrees.

$$F_f = F_e$$

$$v_e = F_e z_e$$

$$= (0.135 - 0.0128j)(0.0281 - 0.1022j)$$

$$= 0.0051 + 0.0134j = 0.0143 < 69.2 \text{ deg}$$

$$v_b = v_e$$

The amplitudes can be obtained from the fundamental relationship

$$x_0 = \frac{v_0}{jw}$$

The displacements are

$$x_2 = \frac{0.484 < -85 \text{ deg.}}{184j} =$$

$$0.00263 \text{ in.} < -175 \text{ deg.}$$

$$x_1 = \frac{0.0143 < 69.2 \text{ deg.}}{184j}$$

$$= 0.000078 \text{ in.} < -20.8 \text{ deg.}$$

The mobility method works equally well for torsional vibration problems. Several quantities must be changed for this type of problem to those indicated in Table III. The application to a torsional system is precisely the same as for a linear vibration. A three mass system as shown in Fig. 3(*A*) would be represented by a schematic diagram as shown in Fig. 3(*B*). The mobility of the points must then be determined.

$$z_b = z_a + z_{ba}$$

$$z_d = \frac{1}{\frac{1}{z_e} + \frac{1}{z_a + z_{ba}}}$$

$$z_e = z_{ed} + \frac{1}{\frac{1}{z_e} + \frac{1}{z_a + z_{ba}}}$$

$$z_g = \cfrac{1}{\frac{1}{z_f} + \cfrac{1}{z_{ed} + \cfrac{1}{\frac{1}{z_e} + \cfrac{1}{z_{ba} + z_a}}}}$$

$$= \cfrac{1}{jwI_3 + \cfrac{1}{\frac{jw}{C_2} + \cfrac{1}{jwI_2 + \frac{jw}{C_1} + \frac{1}{jwI_1}}}}$$

Notice that this equation is a continuous repeating fraction. The solution to this is rather long. Using values for a specific problem proves to be easier than the solution for a general expression. The solution may be simplified in this case by reducing the j so that the preceding equation becomes

$$z_g = \cfrac{-j}{wI_3 - \cfrac{1}{\frac{w}{C_2} - \cfrac{1}{I_2 - \cfrac{1}{\frac{w}{C_1} - \frac{1}{wI_1}}}}}$$

This equation becomes

$$\frac{-j\left[w^4\left(\frac{I_1I_2}{C_1C_2}\right) - w^2\left(\frac{I_1 + I_2}{C_2} + \frac{I_1}{C_1}\right) + 1\right]}{w\left[w^4\left(\frac{I_1I_2I_3}{C_1C_2}\right) - w^2\left(\frac{I_1I_3 + I_1I_2}{C_1} + \frac{I_1I_3 + I_2I_3}{C_2}\right) + I_1 + I_2 + I_3\right]}$$

This is the general solution to the equation for three masses in torsional vibration without damping. The critical speeds can be obtained by setting the denominator equal to zero. This expression can be recognized as the equation usually given for a three mass system.

When more than three masses are considered, the solution becomes more complicated. The solution of these systems can be obtained by using the results of an analysis based on the mobility method. For a free torsional system, the equation is

$$z = \cfrac{-j}{wIn - \cfrac{1}{\frac{w}{C_{n-1}} - \cfrac{1}{wI_{n-1} - \cfrac{1}{\frac{w}{C_{n-2}} - \cfrac{1}{wI_{n-2} - \cfrac{1}{\frac{w}{C_{n-3}} - (..)}}}}}}$$

where n = number of masses.

In this form the right-hand member of the equation can be reduced to a numerator and denominator. The mobility becomes infinite when the force necessary to give it its velocity is zero. At the critical speed, the amplitude of vibration becomes infinite but this is possible only when the mobility is infinite since theoretically it takes no force to give it a velocity. Therefore, if the denominator is set equal to zero, the equation can be solved for the values of w, the critical speed in radians per second.

Table III—Symbols for Torsional Vibration Problems

	Symbol	Units
Moment of inertia	I	lb. in. sec.^{2}
Angular velocity	Ω	rad./sec.
Torque	T	lb. in.
Torsional mobility	$z = \frac{\Omega}{T}$	rad./sec./lb./in.
Torsional responsiveness	$\frac{1}{r}$	rad./sec./lb.
Torsional compliance	$\frac{1}{C}$	rad./lb.

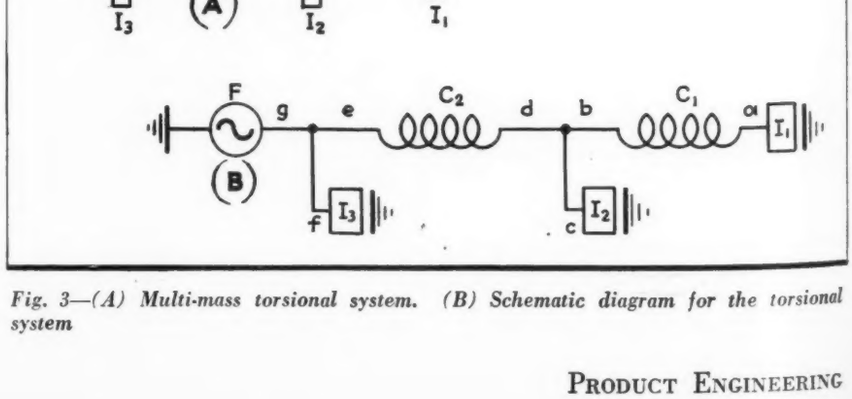


Fig. 3—(A) Multi-mass torsional system. (B) Schematic diagram for the torsional system

Relays Classified by Types To Simplify Their Selection — I

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Control Engineer, Westinghouse Electric & Mfg. Company

PROTECTION of electrical circuits and machinery, and automatic operation may be obtained by proper use of various control relays which detect and thwart certain abnormalities in the circuit or in the drive. These relays are not necessarily the ordinary electromagnetic devices but operate on many principles, the most common of which are electrical, mechanical, magnetical, chemical, and thermal phenomena. Each application is usually best served by one of these principles.

Since the designer of electrically operated equipment must often choose a suitable type of protection and control among many devices designed for the same or similar service, the accompanying tabulation of relays is presented to aid in making the best selection. There are many modifications of each device in use, but in general the principle of operation is the same.

The cost of complete protection is not always justified. The amount of protection and control to be applied to a motor or electrical system is determined by balancing the cost of protection against the importance and value of the machine and its product.

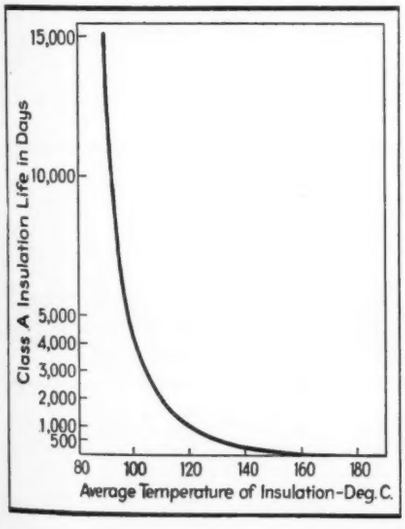


Fig. 1—Relation between life and temperature of class A insulation when tested in a constant temperature oven. In actual service the life is usually much shorter because of the effects of dirt, moisture, mechanical stresses, corrosive fumes, and other indeterminable factors

The majority of the tabulated relay circuits are used solely to prevent overheating, which damages insulation as indicated in Fig. 1. Overheating protection may be obtained in two ways—by limiting the motor temperature directly or by means of an external current relay which has a thermal characteristic proportional to that of the motor.

Thermal overload relays are suitable for most applications because their thermal capacity will generally permit momentary and harmless overloads without shutting down a machine. Care is necessary in their selection and use in order to avoid actuation by starting peak current, which is above full load current momentarily until the load is accelerated to its rated speed. The overload relay tripping time can usually be increased by such means as the use of a saturating transformer for the source of relay heater current or by increasing the thermal capacity of the actuating member of the relay. The rating of an overload relay may be extended by the addition of shunts or transformers.

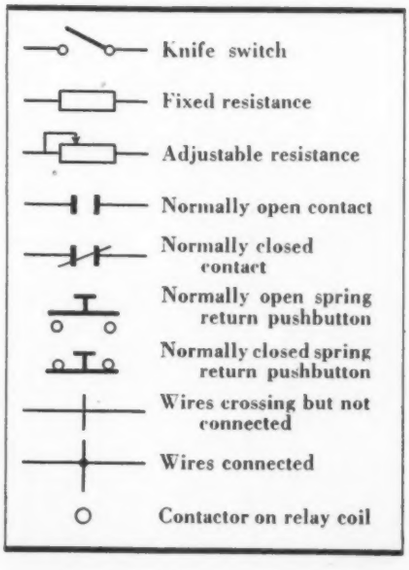
Overload relays are frequently more convenient and economical than fuses. They will often provide more exact protection than a circuit breaker with non-adjustable trip units because circuit breaker trip units are usually calibrated in relatively large units of current as compared with the trip elements of the relay. A circuit breaker with adjustable trip units will generally provide protection equivalent to that of an overload relay. Circuit breakers are usually employed in circuits where their operation is less frequent than a contactor and for greater circuit interrupting capacity.

Another important function of a relay or protective element is circuit protection. Relay operation serves to sectionalize and disconnect an abnormal or disabled circuit automatically so as to prevent stoppage in other essential circuits. Disconnection is usually fast enough to prevent serious damage to the apparatus and production delays.

Other relays may function as the detector of a control system and may act with or without delay to effect the right sequence of operations. Relays with time delay operation usually discriminate between harmless momentary and dangerous sustained abnormal conditions. Additional data on time delay relays were published in PRODUCT ENGINEERING, February, 1942, pp. 86-88. A relay is much more efficient and positive in operation than human manual control because it does not have the frailty of forgetting and is always prepared to act.

Fifteen types of protection or control are included in the table. They are for the control of overload, over-voltage, under-voltage, polarity, motor field current, a.c. frequency, a.c. phase reversal or failure, power factor, closing of circuit connections (plugging and anti-plugging), bearing temperature, and prevention of short circuit, flash-over, and overspread. Only the first listed type of control is included in this issue. Other types of relays and devices will be tabulated in subsequent issues.

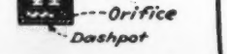
Symbols Used in the Electrical Diagrams Contained in the Table on the Following Pages



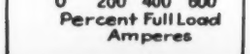
I—OVERLOAD PROTECTION

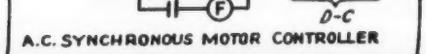
TYPE AND APPLICATION	MECHANICAL CONSTRUCTION	PRINCIPLE OF OPERATION	TYPICAL OPERATING CURVES	TYPICAL APPLICATIONS TO MOTOR CONTROLLERS OR GENERATOR CIRCUITS
1 FUSE. A fuse is used when overload and short-circuit protection cost must be minimized. When applying fuses, maximum ratings should approximate 150% full load current of d.c. and a.c. wound rotor motors, and 250% to 300% of full load current of squirrel-cage motors.	Non-Renewable Cartridge Type of Fuse Fibre tube, A, B, Insulating powder, Fuse wire, Ferrule terminal Renewable Link Knife-Blade Type of Fuse A, B, Renewable link, Fibre tube, Clamping sleeve, Contact blade	Properly applied fuse carries 110% full load current indefinitely. At 150% full load current, fuse link melts and breaks circuit in specified time in accordance with rating.	60 amp., 100 amp., 150 amp., 200 amp., 250 volt fuses Seconds Blowing Time: 480, 360, 240, 120, 0 0, 200, 400, 600 Amperes	Dch. res., Shunt field, Arm, Serf., Stop, Start, M, Ma — D.C. MOTOR CONTROLLER Motor, Start, Stop, M, Ma — A.C. SQUIRREL-CAGE MOTOR CONTROLLER Motor, Motor field, Start, Stop, Time, F, Ma, Dch. res., Fld. rheo., D-C — A.C. SYNCHRONOUS MOTOR CONTROLLER A, B — FUSE WIRING SYMBOL
2 INSTANTANEOUS MAGNETIC RELAY. Protects against high overloads. Usually calibrated to trip instantaneously at a current above motor peak starting current. Interrupting capacity of line contactor determines maximum current that can be interrupted safely.	Moving contact, 1, 2, Stationary contacts, A, Coil, Armature, B, Iron frame	Current through coil produces force tending to lift armature and to break contacts. Weights or springs opposing armature movement determine current value at which relay instantly trips.	Armature Restraining Force (Weight or Spring) 0, Trip Amperes	OL, 1, 2, A, B — RELAY WIRING SYMBOL Dch. res., Shunt Fld., Arm, Serf., Stop, Start, M, OL, Ma — D.C. MOTOR CONTROLLER OL-1, OL-2, Motor, Start, Stop, M, Ma — A.C. SQUIRREL-CAGE MOTOR CONTROLLER
3 TIME DELAY MAGNETIC RELAY. Protects running motor against sustained currents only slightly above full load current. Dash-pot or other damping means prevents tripping on peak starting current or momentary high overloads.	Moving contact, 1, 2, Stationary contacts, A, Coil, Armature, Iron frame, B, Fluid, Piston, Orifice, Dashpot	Addition of dash-pot to No. 2 relay prevents tripping on starting or momentary high currents. Delay period is inversely proportional to sustained overload current. De-energization of power circuit after relay operation permits instant return of armature. Relay may be designed for closing or resetting contacts automatically, manually or electrically. Number of turns and current capacity of coil determine specific rating.	Tripping Time 0, 200, 400, 600 Percent Full Load Amperes	OL, 1, 2, A, B — RELAY WIRING SYMBOL M, OL-1, OL-2, Motor, Motor field, Dch. res., Fld. rheo., Start, Stop, Time, Ma, F, D-C — A.C. SYNCHRONOUS MOTOR CONTROLLER
4 DE-ION BORIC ACID POWER FUSE. Used with low inter-	Spring	At certain current value main	*Time shown is melting time based on fuses starting cold at 25°C ambient.*	A, B — FUSE

loads.

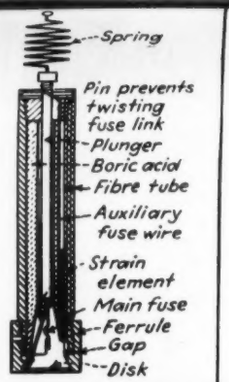


electrically. Number of turns and current capacity of coil determine specific rating.

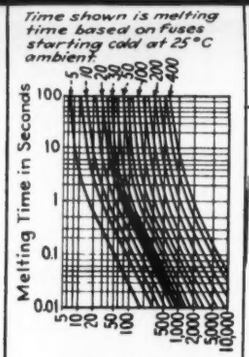


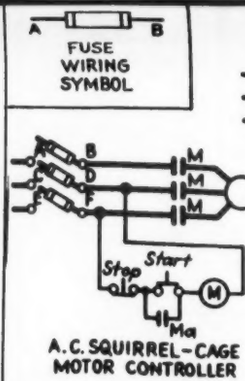


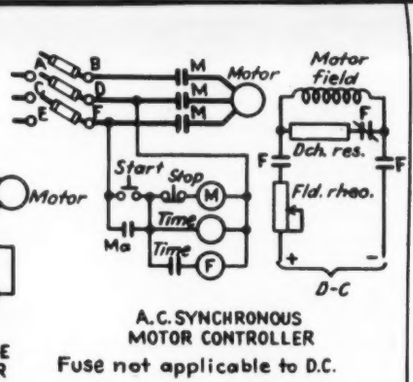
4 DE-ION BORIC ACID POWER FUSE. Used with low interrupting capacity switches on a.c. circuits to obtain high interrupting capacity. Installation of single circuit breaker of equal capacity and disconnecting means usually costs 20% to 50% more. Fuse is usually arranged to serve also as a means of disconnection. Links are renewable in ratings of 7.5, 15, 23, and 34.5 kv with interrupting capacities of 0.45, 0.75, 1.0 and 1.2 million kva respectively.



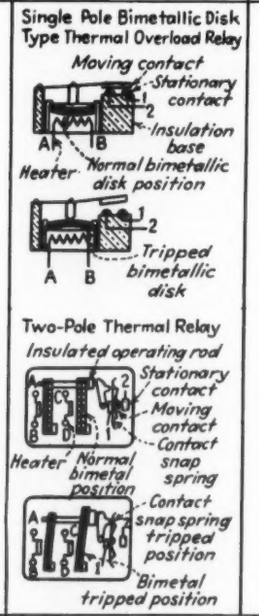
At certain current value main fuse link burns out and releases plunger, which pulls a.c. arc through boric acid in center of tube. Auxiliary fuse wire interrupts small arc. Larger arc is extinguished by de-ionizing action of water vapor, which is produced by reaction between arc and boric acid, when de-ionization of air medium exceeds rate of ionization by the arc.



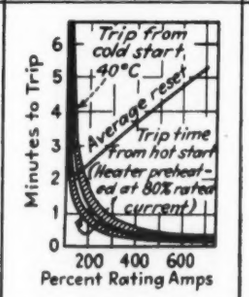


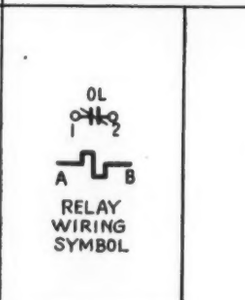


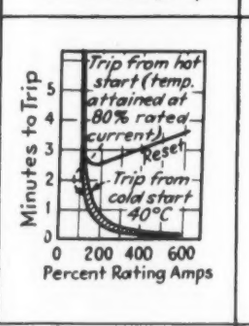
5 THERMAL OVERLOAD RELAY. Protects against sustained overload currents at 115% to 125% full load motor current to values slightly exceeding locked rotor current. Usually ideal for running protection because thermal lag prevents tripping on starting or momentary high currents. Two separate relays or a combination relay with two or more current elements are usually employed on 3-phase a.c. circuits to protect all phases and prevent the motor operating on single phase. Relay must have fuse or circuit-breaker protection against short circuits.

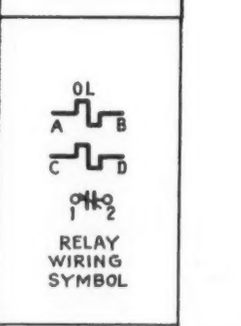


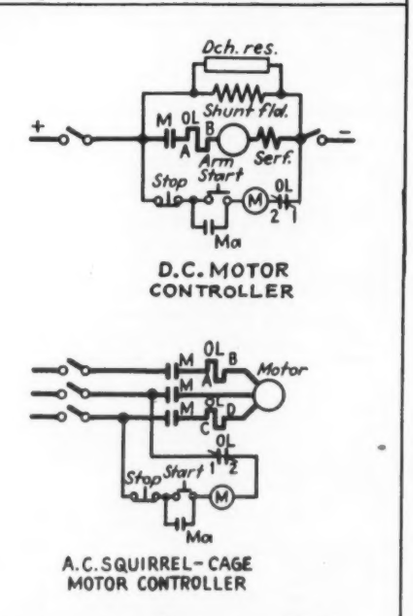
Heat expands one side of bimetallic disk or strip more than the other, thus causing warping or deflection which will make or break a contact. Since deflection of flat strip is slow, a quick acting contact mechanism is usually employed to prevent burning of contacts. Disk type elements reverse convexity suddenly. Tripping time is inversely proportional to sustained overload current. Cooling rate of bimetal determines times for reset. Relays may have automatic or manual reset.


Trip from cold start, 40°C
Average reset
Trip time from hot start (Heater preheated at 80% rated current)
Minutes to Trip
Percent Rating Amps

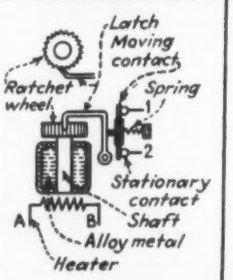




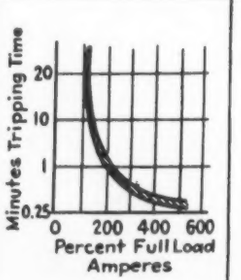


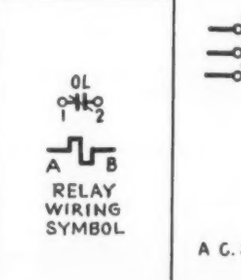


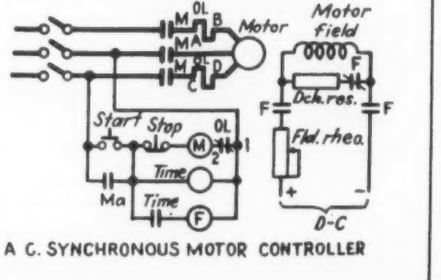
6 THERMAL MELTING ALLOY RELAY. Gives inverse time limit protection against sustained overload. Usually designed for manual reset since there is no automatic force available for resetting.



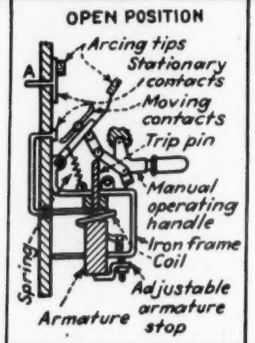
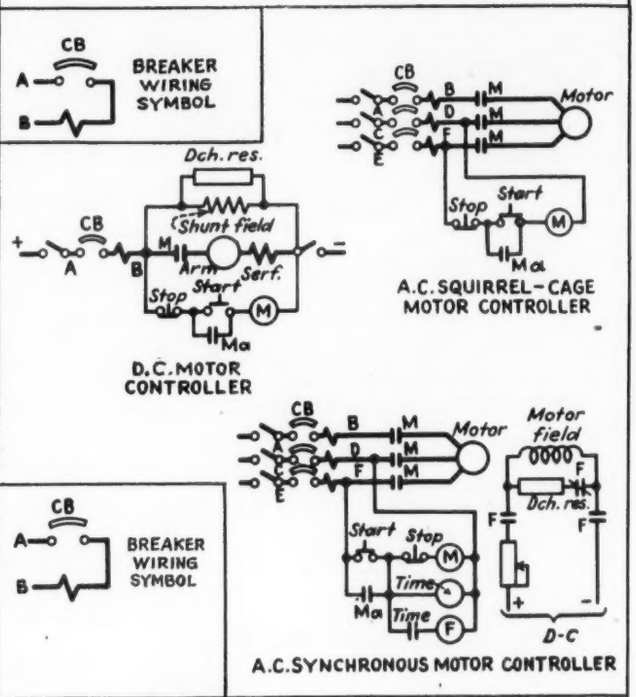
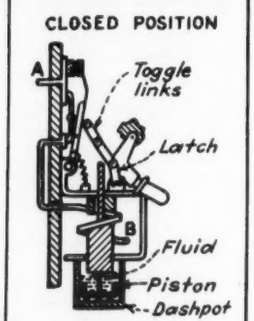
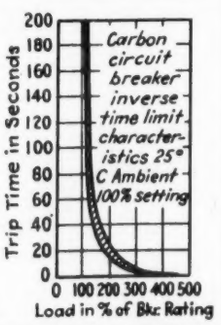
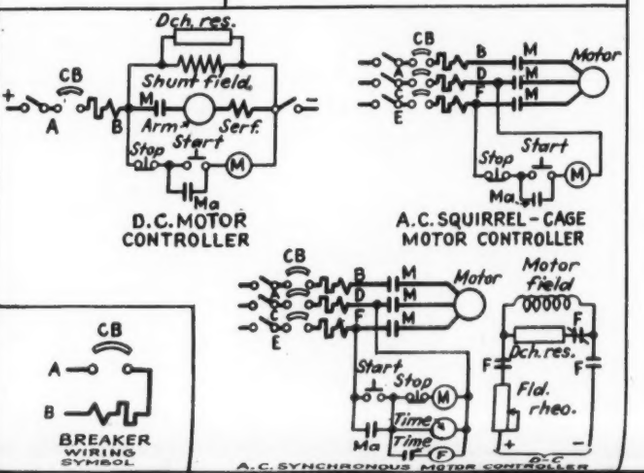
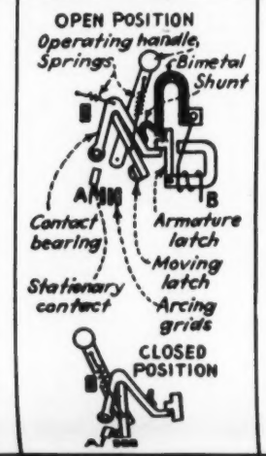
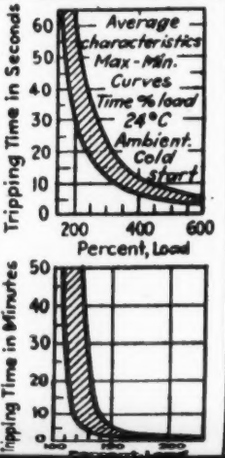
Ratchet wheel and shaft, to which torque is applied through spring latch, are restrained from rotating by low melting alloy in bearing box. Melting of alloy at predetermined temperature produced by heating coil when sustained overload current occurs, permits contacts to open. Resetting awaits refreezing of alloy. All friction is overcome by use of a strong operating spring.





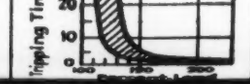


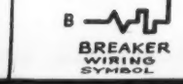
I—OVERLOAD PROTECTION (*continued*)

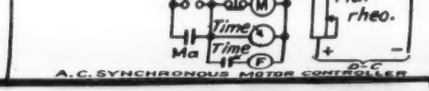
Type and Application	Mechanical Construction	Principle of Operation	Typical Operating Curves	Typical Applications to Motor Controllers or Generator Circuits
7 Instantaneous Magnetic Trip Circuit-Breaker. Air circuit-breakers have higher interrupting current capacity than most contactors. They may be considered a combination of overload relay and circuit opening device. They are often made for a multiplicity of main circuits and may be equipped with various operating and tripping mechanisms.		Magnetically actuated tripping pin opens toggle held arcing contact and main current carrying contacts at specified overload current.		
8 Time Delay Magnetic Trip Circuit-Breaker. Air circuit-breakers with dash-pot damping are a pplied widely on d.c. and low-voltage a.c. circuits. Dash-pot permits closer setting for tripping current because momentary or starting current peaks will not trip breaker. Oil circuit-breakers, whose mechanisms and arc quenching principles differ from those shown, are usually applied to high voltage and high power a.c. circuits.		Addition of dash-pot on circuit-breaker delays tripping time in inverse proportion to sustained overload current. Illustrated breaker mechanism contacts cannot be held closed manually on high currents as the tripping device will operate regardless of whether breaker handle is held or is free. This mechanism is called "trip free."		
9 Thermal and Magnetic Trip Circuit-Breaker. Combined inverse time delay thermal and instantaneous magnetic trip protection is obtained by a relatively simple, low cost, and small size circuit breaker for low voltage a.c. and d.c. circuits. Frequently applied to line-starter and similar apparatus for overload and short-circuit protection and disconnect switch service. Capable of interrupting 5,000 to 10,000 amperes. Single and multiple pole assemblies are available.		Contacts are closed by handle, which is connected to moving contact by a biasing spring. Thermal overload protection is provided by bimetal element which moves trip latch when sufficiently heated. Instantaneous magnetic trip for predetermined high currents is provided by series coil and electro-magnet. When latch is made ineffective by thermal or magnetic action, contact arm bearing moves to such a position that the contact is opened by biasing spring.		

peres. Single and multiple pole assemblies are available.

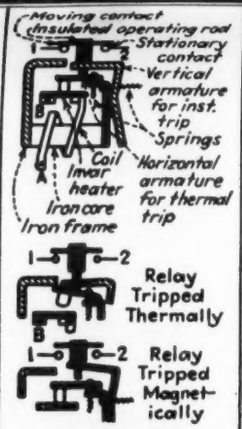
position that the contact is opened by biasing spring.





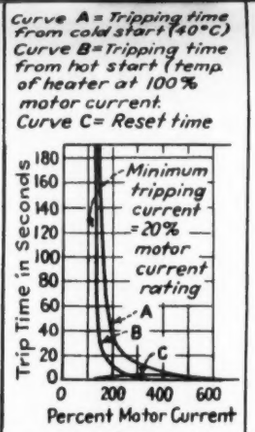


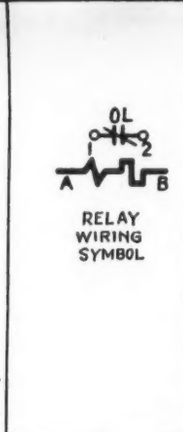
10 THERMAL AND MAGNETIC RELAY. Used to protect d.c. motors against overload. Delay of thermal element before opening of control contacts is inversely proportional to current for low and medium overloads of 120% or more of full load motor current. Magnetic element trips contacts instantaneously on high overload currents of 200% or higher.

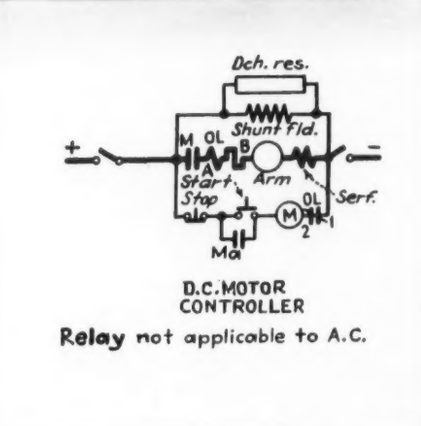


Thermally actuated armature is normally held by spring and magnetic attraction of "Invar" heater carrying motor current. Heater magnetism is lost at about 465 deg. F. and armature is attracted to magnetized frame, thus opening control contacts. Separate magnetically actuated armature operates instantly on higher current.

Thermal relay may be adjusted to operate at 12% to 20% above motor current. Magnetic trip may be adjusted to operate at 200% to 600% full-load current.

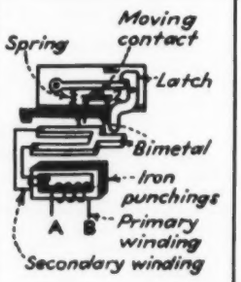




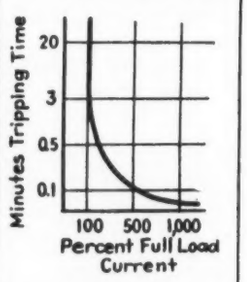


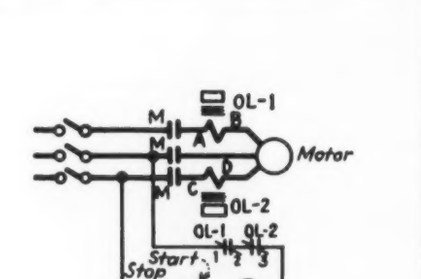
Relay not applicable to A.C.

11 TRANSFORMER TYPE THERMAL RELAY. Current element withstands more severe overload and short circuit currents than some other thermal relays. Can be applied only to a.c. circuits; therefore usually built with two poles. Trips at specified value of primary ampere turns. The construction shown automatically compensates for ambient temperature.

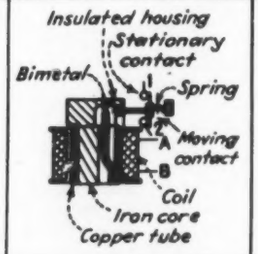


Bimetal element is deflected upward by heat produced by secondary transformer current, which is determined by number of turns and current capacity of primary coil. Illustrated relay is compensated for ambient temperature changes by upper bi-metal element which neutralizes deflections of heated element caused by ambient temperature.

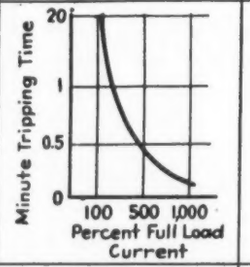


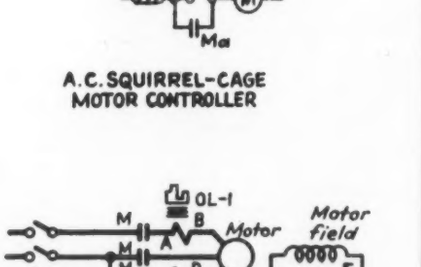


12 INDUCTIVE THERMAL RELAY. Especially suitable for oil immersion. With automatic reset it should be used only for protecting low voltage protection circuits. For two-wire control circuits only the manual reset or an auto-reset relay plus a reset relay should be used, the latter serving to "lock out" the control when an overload occurs.

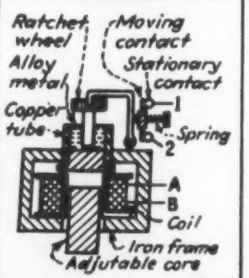


Copper tube inside coils and around an iron core acts as a short-circuited secondary of transformer. Heat generated in tube, which is proportional to coil current and number of turns is transmitted to bimetal element, causing it to deflect and open control contacts when damaging overloads occur.

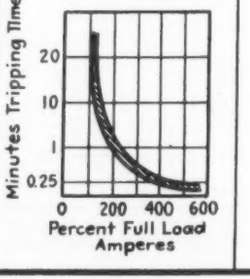


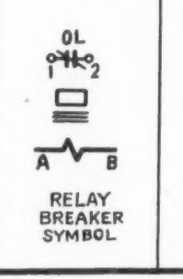


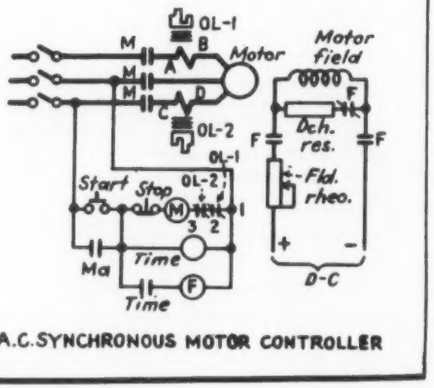
13 INDUCTIVE MELTING ALLOY RELAY. Applicable only to a.c. circuits and usually has manual reset. Differs from No. 6 only in method of heating alloy metal. Relay is adjustable within certain limits for each coil.



Heat from inductively heated copper tube is transmitted to low melting alloy around shaft of ratchet wheel. Melting of alloy at predetermined temperature produced by sustained overload current in coil permits spring to rotate ratchet wheel and open contacts. Heat generated in tube may be varied by changing position of core, thus varying the magnetic flux in the tube.

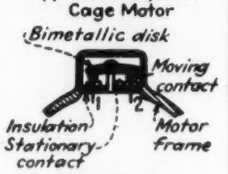
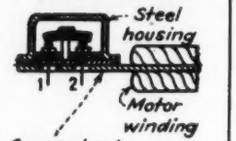
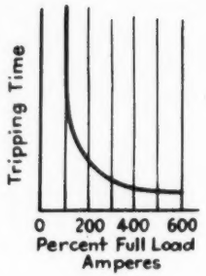
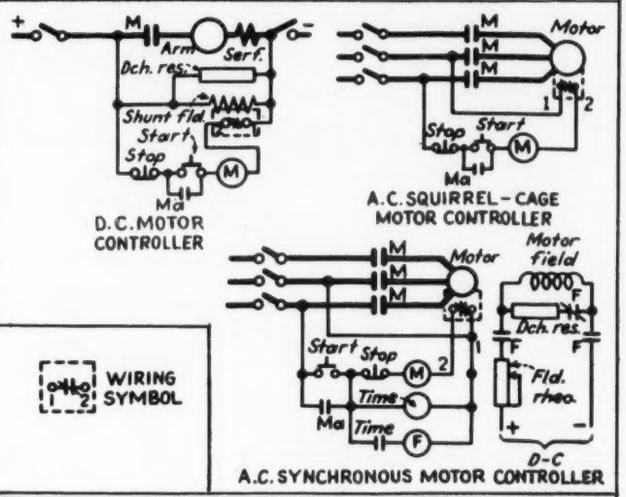




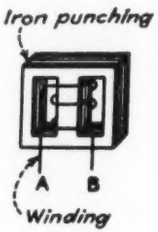
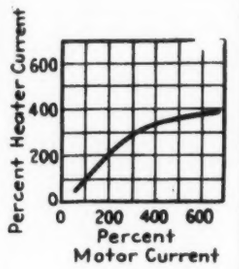
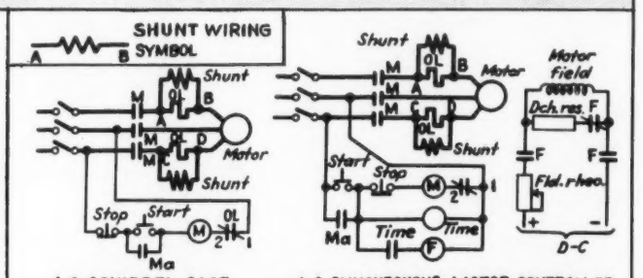
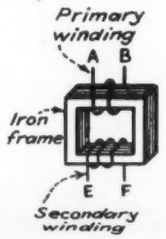
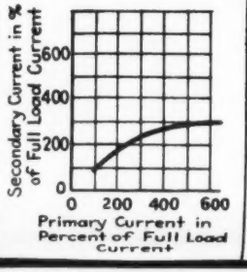
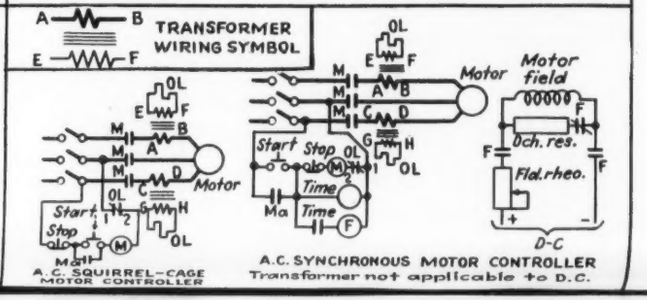


A.C. SYNCHRONOUS MOTOR CONTROLLER

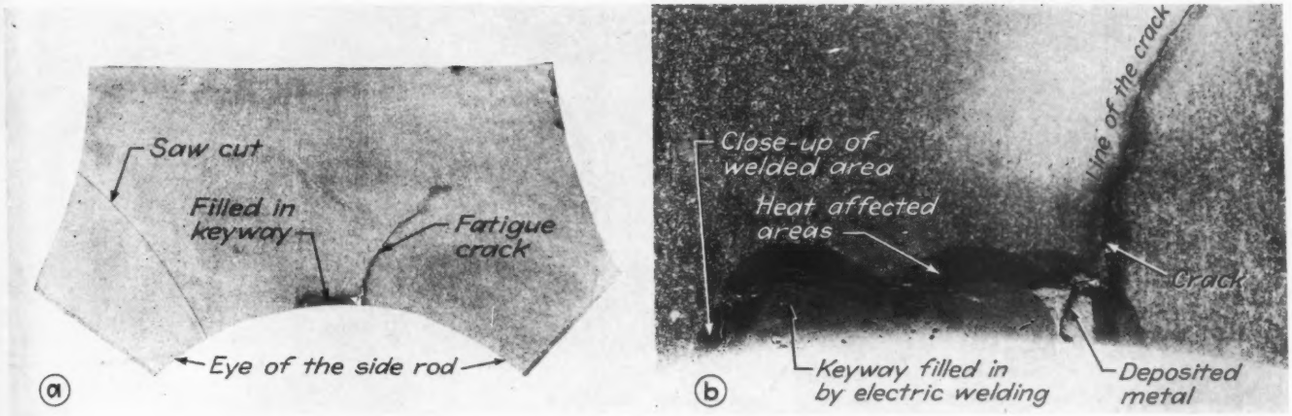
I—OVERLOAD PROTECTION (*continued*)

Type and Application	Mechanical Construction	Principle of Operation	Typical Operating Curves	Typical Applications to Motor Controllers or Generator Circuits
14 Thermostatic Disk. Protects against over-heating of motors when caused by such conditions as too frequent starting, sustained or frequent overloads, high ambient temperature, ventilation failure or abnormal voltage. Additional overload apparatus must be used if protection is required against stalling and phase failure. Bimetallic disk is usually mounted on frame of squirrel-cage motor and on winding of synchronous wound rotor or d.c. motors. It may open power circuit by means of a contactor or close an alarm circuit.	Thermostatic Disk Applied to Squirrel Cage Motor  Thermostatic Disk Applied to Windings of D-C, Wound Rotor, or Synchronous Motor 	Principle explained for No. 5. Actual motor heat rather than that produced by heating coil actuates bimetallic disk. Resetting awaits cooling of motor frame or winding.		

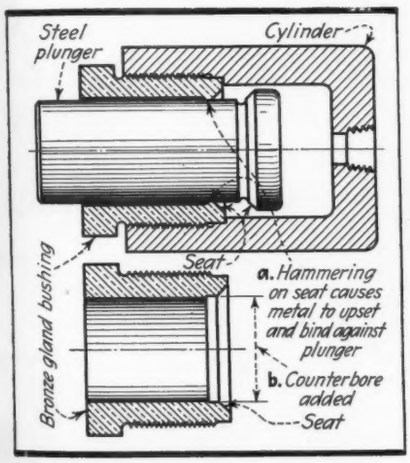
II—OVERLOAD RELAY ACCESSORIES

1 Saturating Inductive Shunt. Connected in parallel with heater of a.c. thermal overload relay to increase tripping time during starting of high inertia loads and to protect heater from high overload current. Less expensive than a current transformer.		When thermal overload relay heater carries rated current, potential drop across heater is below saturation voltage of reactor and very small current is diverted from heater. Reactor saturates at high over-currents and a large current is shunted through it. Winding current capacity and number of turns determine rating.		
2 Saturating Current Transformer. Used to extend operating range of a.c. thermal overload relay heater, to increase tripping time, and to protect heater against high overload current.		When primary current is low, secondary or heater is directly proportional to ratio of primary to secondary winding turns. High primary current saturates iron core and ratio of secondary to primary current diminishes.		

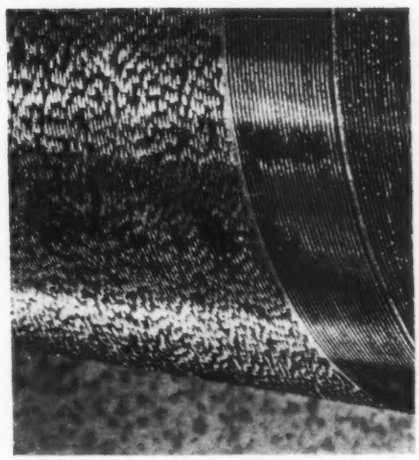
Causes and Cures



Keyway of salvaged side rod was filled in by electric welding. Welding was of poor grade, and the rod cracked in service. Crack started at the square corner of the original keyway. The line of the weld indicates lack of fusion and there are defects in the deposited metal. Designers should insist that proper welding technique be used when salvaging stressed machine parts, particularly where fatigue is a factor. If such welds are necessary, proper welding electrodes should be selected to protect hot metal from oxidation and to insure proper fusion of metal. In this case the square corners of the original keyway should be thoroughly fused with the deposited metal; fatigue cracks find an excellent starting place in such corners which are not carefully welded, and often have developed failures.



Steel hydraulic plunger was mounted through a packingless close-fitting bronze gland bushing as shown in sketch (*a*). A 45-deg. seat on the head of the plunger engaged a similar seat on the inner face of the bushing when the plunger was fully extended, thus providing a positive stop, and also sealing-off hydraulic leakage past the gland. After some months' service the plunger seized. It was discovered that the hammering action had upset the seat slightly, reducing the diameter of the bore until it gripped the plunger. The condition was cured by counterboring the inner end of the bushing at the seat for a short distance.



Design engineers who have specified roughened surfaces as foundation for sprayed metal finishes may have felt a little guilty about all the expensive tools their specifications necessitated, such as special knurled and dove-tail shaped tools. The problem never was as difficult as all that, it now appears. Recently Carboloy engineers reasoned that if you know how to produce a smooth finish by grinding a tool correctly, it ought to be possible to produce a rough finish by grinding the tool "all wrong." So they ground a standard cement-carbide tool to unorthodox shape, and turned out the rough finish shown at left.

ACCUMULATION OF TOLERANCES may often cause interference between moving parts. In one such case, evidence of slight interference between a pinion and internal gear in an aircraft engine showed up in production tests. Engineers resinspected the parts and found that they met specifications, so dimensions and tolerances were checked and a possible interference was found. Removal of considerable metal was required to correct the difficulty, and some time was spent in "juggling" the figures so that exact interchangeability of parts could be obtained. No sooner was the cure found and put into effect that the fault became chronic in engines already off the assembly line. Had it not been discovered early, it would have tied up an important production schedule.

RAZOR STEEL DOCTOR BLADES which scrape the soap from steel drying rolls in a soap manufacturing plant caused a shut-down of 10 min. every eight hours while they were honed. Periodic shut-down meant a 500-lb. production loss every shift. Corrosive action of wet soap quickly dulled the blades. In an attempt to reduce this combined abrasion and corrosion problem, doctor blades made of heat-treatable Monel metal were substituted. Blades are now never removed before 60 hr. service.

U. S. Steel

MICROSCOPIC EXAMINATION and microphotography exert a great influence on the development of steel. Microscope and camera are among the important tools used by the physical metallurgist in studying internal structure which in turn is intimately related to the properties of the metal.

New Uses for Photography In the Engineering Department

A survey of photographic methods and procedures as used in engineering departments to speed up routine work and to facilitate research studies. The field for photography extends all the way from the photo-template process, now receiving so much attention in the aircraft industry, to the lesser publicized but just as valuable applications of the X-ray and of high-speed photographic equipment.

CONCURRENT with the advances made in the quality of the blueprint and whiteprint materials used to reproduce tracings, along with the improvements in the printing and developing machines, more and more time is being devoted by engineering department executives to the subject of finding new methods for saving time in routine procedure.

For preliminary design and detail work, conventional pencilled line drawings and tracings are still unsurpassed in meeting the needs of most engineering departments, especially where the number of blueprints or whiteprints needed for shop use and records is small. For the purpose of shortening the time required for making line drawings, and also for helping workers, who are not skilled in reading blueprints to get a quick mental picture of an assembly or part, photo-tracings have been found to possess many advantages. (See "Photo-Tracings, Their Use in Making Pictorial Blueprints," PRODUCT ENGINEERING, January 1942). Comments and instructions can be readily lettered on the photo-tracing before making continuous-tone blue- or whiteprints for shop use.

Engineers in the aircraft industry have been the pioneers in devising photographic methods to reduce the cost and time required in lofting and the making of templates. Glenn L. Martin, Lockheed, General Motors and others have developed systems that differ in details, whereby drawings, photographs, template outlines and similar profiles are transferred to photo-sensitized metal sheets or other permanent bases. In these systems four general photographic processes are employed.

1. Projection printing method in which the original drawings are made on sheet metal, then photographed on a glass negative in a huge camera. The glass negative is then used to make projection prints on a sensitized surface. The projected image can be enlarged or reduced to any predetermined scale. An accuracy of 0.001 in. per ft. is claimed for good camera equipment.

2. Contact printing from tracing cloth or paper onto a more stable base.

3. Contact printing from a drawing onto a glass base. Prints so made are mirror images, but for many jig drawings and template outlines it is satisfactory to turn the glass plate over and look through the back of the plate. A true right image will then be seen. When notations or written directions are needed on the template drawing, it is only necessary to make a glass reproduction by contact with the original glass drawing. A drawing so produced will be a negative that may be reproduced with all its detail on any base desired.

4. Contact printing from drawings on metal, wood or other material, a surface of which has been coated with a composite substance that has been rendered luminescent by exposure to X-rays. Any other base coated with photo-sensitive emulsion can be exposed to this X-ray original. The printed images will be negative or mirror. If positive, true images are desired, a glass plate can be exposed to the X-ray plate with visible light. A variation in the X-ray system is also used to make metal negatives.

Film instead of the glass plate applications mentioned has been tried, but the expansion and shrinkage during processing and that caused by atmospheric conditions has led to standardization on glass plate.

Advantages of the photo-enlarging process lie in its flexibility. Drafting time is saved through scale reductions for such purposes as mock-ups. Likewise, calculations for the shrinkage of die-castings are eliminated through proper enlargement of drawings. Allowances can be made for folds and corners in sheet which is to be formed. Small-scale or full-scale drawings for shop or field use can be made with the ease of ordinary photographic enlarging. The value of such flexibility is shown by the following example.

A rush order for a complete new wing structure was received by an engineering department. Ordinarily, with drawings required for each section, the job would have taken days to draw and to cut templates, but by scaling drawings photographically from a master drawing, the job was done overnight.

If much scaling work is required by an engineering department, particularly accurate scaling, the capital outlay for precision optical equipment is probably justified. On the other hand, not many concerns outside the aircraft industry, have any great call for enlargements or reductions in their drawings. For their work, contact printing does an inexpensive, accurate job. When a company needs accurate contact prints but can allow tolerances in scaling, satisfactory work can be done with a relatively inexpensive enlarging camera.

Because of its destructibility, the glass negative for contact work is usually unsatisfactory except for simpler drawings. The X-ray system, producing the master drawing on metal or other stable base, is easy to operate, accurate and fairly inexpensive to install.

For all types of photo template making, it is desirable that the engineering department have the metal sheets prepared in their own plant if large quantities or sizes are required. Some smaller sizes of photo-sensitized metals, that are available commercially, may be stored as safely as enlarging or printing paper. These may fill the requirements for an occasional, small template.

In the Glenn L. Martin system, a photosensitive solution, supplied by Martin, can be coated directly on practically any metal, wood, cloth, linen, paper, glass or plastic. Processing is like that in any standard photographic practice —developer, shortstop, hypo, and wash. Because the solution can be applied to any shape of surface, the process has interesting possibilities. For instance, if additional details such as rivet holes, bolts, or lettering are to be added to a peculiarly shaped part or fixture, placing of the detail can be done photographically without resorting to a draft-

The Glenn L. Martin Company

Photo-template camera recording a loft drawing, apparatus for holding the negative is in room in back of the camera. When loft drawing shown here is replaced by a sensitized sheet the negative is projected back through camera to make print

ing job which may be difficult. First, an original part is altered as desired in the shop. A photograph is taken of this part. Then all parts upon which the alteration is desired are coated with the photo-sensitive emulsion. The original negative is projected back upon the sensitized surface just as in photo enlarging, thus marking alterations on all parts the same as the altered original.

Lockheed laminates Eastman Matte Transfer Paper on sheets of galvanized Paintgrip, a specially coated metal sheet supplied by The American Rolling Mill Company. Original drawings, from which photographs are made on glass negatives, are also made in the loft on the Armco sheet. Again, exposed sheets are processed by standard photographic procedure. Both Martin and Lockheed systems allow the use of either ink or pencil lines.

Electrolytic Scribing

Although not strictly photographic, an electrolytic system of scribing templates or patterns is a part of the program of rapid reproduction at Lockheed. In this, the engineering drawing is scribed on Paintgrip, with a sharp instrument cutting through to the base metal, to form the master layout copy. The scribed sheet is coated with ferrous sulphate solution and placed in contact with another metal sheet upon which copy is to be made. The two are placed in a hydraulic press, and when an electric current is passed between them, the design of the master copy is etched into the copy sheet. When given a coating of protective lacquer, the copy is ready for the template cutter. Advantages of the electrolytic process are speed and inexpensiveness. It operates at a fraction of the cost of the photographic process, but the size of prints which can be reproduced is limited by the size of the press.

All template processes have common advantages in their ability to produce virtually indestructible drawings for shop and field. Confidential drawings can be made theft proof by having them on large metal sheets which are practically impossible to conceal. Many tools, fixtures, jigs and gages can be fashioned from templates. In many cases, dies can be eliminated by using a master template with which to cut templates in quantity. Templates can be used for the direct manufacture of dial faces, graduated instrument and machine scales, and name plates. Applications for templates are limited only to the ingenuity and imagination of the engineer.

Success of template processes depends upon the engineering department's ability to supply full-scale drawings with clearly defined lines for contours, holes, bolts and bends. Complete instructions for fabrication should also be given.

Photography in Testing

Photoelastic stress analyses; recordings of vibrations, spectra, and other physical phenomena; photomicrography; and testing are facilitated with the help of high-speed photography—still and motion picture; X-ray; and high-speed X-ray.

High-speed still photography, with equipment such as stroboscopes, the Edgerton speedlamp and similar devices, can be advantageously employed in checking the behavior of exposed machine elements in motion such as synchronous motors, propeller tips, and shafts. Special high-speed apparatus has been used by Westinghouse engineers (see "Photographing Electric Arcs in Liquids," *Photo Technique*, February 1941) to study the extinction of arcs in oil and water.

High-speed cinematography makes possible the production of slow-motion pictures or sequence of interrupted still pictures for the study of all types of exposed mechanical and electrical parts. A recent study by L. T. Weller and E. M. Watson of General Electric Company recorded, through the use of an

Eastman high-speed 16-mm. motion picture camera, what takes place when metal is cut by a tool. These observers have suggested this system for the study of the action of chip flow as influenced by rake and clearance angles of various cutting tools, of the effect of coolant on chip flow, and the effect on the material from which the chip is being torn away.

Welds, plywood parts, small assemblies, hydraulic fittings, and castings in general can be inspected by X-ray. X-ray pictures of castings show varying densities on negatives where flaws occur. In the aircraft industry castings are X-rayed and classified in accordance with their stress requirements. Now of great importance in ballistic studies, high-speed X-ray is also used to study the effect of rapid motion on inclosed machine elements such as pistons and turbine impeller blades.

Ordinary still and motion picture photography also has many valuable uses. Cine cameras operating at normal speeds make records of the action of plane landing gears and of dials of test planes during flight. Air flow on different parts of planes in flight is studied through motion pictures of small threads attached to the surface of the plane. Photography is an important adjunct of oscillographic equipment for the maintaining of permanent records.

Characteristics of materials are largely determined photographically—through X-ray diffraction patterns, spectrum analyses, and metallographic cameras. With a simple camera and radioactive tracers, engineers of Westinghouse have been able to show that phosphorus concentrates at blow holes in iron or steel.

Vibrations are recorded photographically in the testing of airplane parts. Seismographic recordings on film are used by geologists and physicists in modern prospecting or oil and metals. Small cameras are also placed in drilling bits to photograph the course of the drill and thus determine drift conditions. Aerial photography also helps the geologist as well as the civil engineer. For the former, it saves the work of prospecting great areas of rough terrain and shows possible routes for pipe lines. Engineers use aerial photography in surveying sites for plants, dams, bridges and road construction.

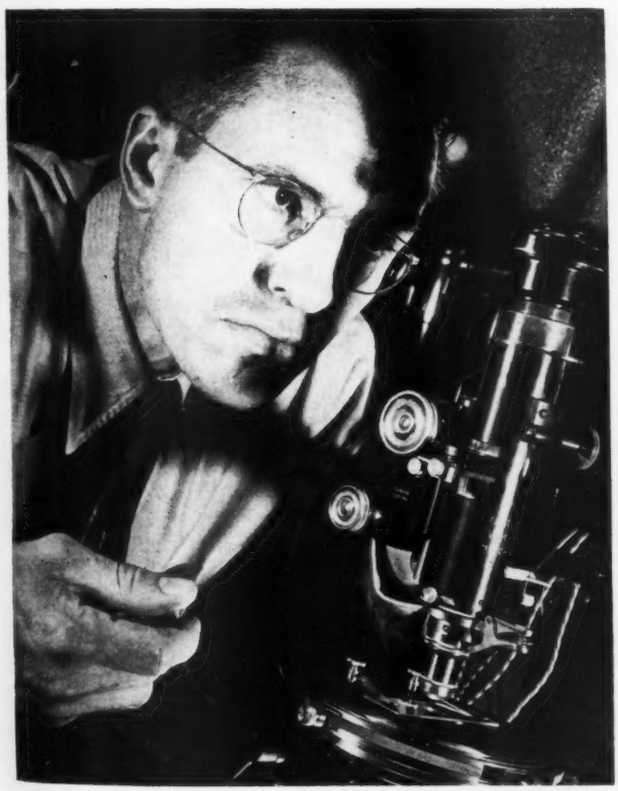
Microfilming

Millions of documents, drawings and other confidential or essential data are now being photographed on microfilm. Either 16 or 35 mm. film is used, depending upon the size of copy. Projection of the small negative back to size will produce clean-cut, detailed enlargements. Advantages of the system are threefold: (1) Small storage space or vault can handle thousands of drawings and data that normally would take up a major portion of an office or laboratory; (2) As many sets as desired may be made for storage at different places for maximum insurance against loss or damage; (3) Large numbers of drawings can easily be carried from plant to plant in a small, compact package. Microfilming is now fast and inexpensive, and most large plants have it on their "must" list.

Photography with infra-red sensitive emulsions can be used to study heat effects on parts and materials, such as welds, cylinder heads, exhaust manifolds, and processed metals.

The use of photography in industrial education is a field not to be neglected by engineers. Photography offers all its branches—still, silent movies, sound movies, stereoscopic stills, stereoscopic motion pictures, and animated sequences, all types in color or black and white—to employee training programs. Still photographs, straight or retouched, illustrate manuals and booklets.

With all the advantages offered by this versatile science, photography is a subject about which the progressive engineer must be informed.



Westinghouse Electric & Mfg. Company

Making permanent records of how things look under a high power microscope with this combination of microscope and camera. Microchemist is poised ready to snap just the right view

Westinghouse Electric & Mfg. Company

One 10,000th of a second is the time needed for the slit in edge of the wheel to fly past camera lens in taking a picture of an electric arc in the glass bulb

Question and Comment

Carlson Submits Data on Swedish, U.S. Spring Steels

To the Editor:

It is common knowledge to many reputable spring companies specializing in manufacturing thousands of different type springs for varied applications, and to wire-drawing companies specializing in producing high quality spring wire that Swedish steel rods produce music wire with a much higher tensile strength, longer fatigue life, better uniformity of structure and qualities superior in many respects, especially for use in automatic coiling machines, to American music wire.

Such facts have been published many times and are well known by many engineer-designers and research men throughout the world. It is purely wishful thinking to believe that American steel spring wire surpasses or even equals the quality of the Swedish product, except perhaps in some special, isolated cases.

In the article under discussion, there were submitted several itemized reasons for this statement. They were removed from the article in editing. Briefly described, the more important reasons are that Swedish ore is of a much higher quality, which means less doping and refining; the impurities are fewer; the practice of pouring smaller billets produces a smaller and better dendritic structure with less piping, seams, etc. Another important reason is that Swedish mills spend more time in processing their product. They produce only 40 tons per day whereas a similar American mill produces 200 tons per day.

The facts presented in "Spring Steels" were accumulated during the past decade and agree with similar data obtained by many outstanding research engineers whose technical papers have been published with similar findings.

It is a foregone conclusion that the collection of data for the preparation of any article on this subject requires not only many years of research and intimate association with many other companies but also access to the records of the A.S.M.E. Special Research Committee on Mechanical Springs, which have papers dating back to 1678 when Robert Hooke in his "De Potentia Restitutiva" stated "Ut Tensic sic vis" (the power of any spring is in proportion to the tension thereof). These records contain copies of all technical articles ever published including those printed in foreign countries.

Let us examine some of the facts compiled by several wire-drawing and reputable spring manufacturers. In the tensile strength tables the values compared indicate which wire is stronger and need no further explanation.

So far as fatigue life is concerned, the writer has also made numerous tests on many types of steel wire springs and the results frequently agree with the tests made by others. The only time American steel compares favorably is when the springs are stressed at low values. Under such conditions, there is no need to use the high grade steel obtained from Sweden. Average American steels will have a long fatigue life only when stressed low; at high stresses the Swedish steels have a much longer fatigue life—in many cases as much as 100 percent longer. Many technical papers concerning fatigue life, are available at the Engineering Societies' Library, 29 W. 39th Street, New York, and are available to those interested in such matters without charge.

The importance of the thousands of different spring applications in War Production equipment cannot be overemphasized. Hundreds of such applications pass the scrutiny of the writer each week; too many of them have springs with stresses entirely too high. Granted that it may be in keeping with present sentiment to state that American wire is better than Swedish, an engineer must, nonetheless, adhere to facts. Let us review these facts:

1. Where low stressed springs of small diameter wire are used (under 60,000 p.s.i. including allowances for curvature correction factors) any good spring steel will have a long fatigue life.

2. For springs having high stresses (85,000 to 125,000 p.s.i., and this covers the large majority of spring applications), the fatigue life will be much shorter when American steel is used.

3. Swedish steel is practically impossible to obtain today. Product designers especially those designing ordnance material, should therefore use lower stresses than customarily specified.

4. Occasional spring breakage, due to poorer uniformity of structure, occasioned by inclusions, seams, piping, etc., is more prevalent today than ever before.

5. More attention should be paid to design factors including limitations of space, tolerances, loads and deflections, as well as design stresses, so that those products such as torpedoes, bombs, guns, planes and tanks will not bog down due to the shorter fatigue life of American steel spring wire.

Copies of an 11-page reprint of a series of articles describing many spring steels, published in the January, February and March numbers of PRODUCT ENGINEERING, are available to those interested upon request to the Lee Spring Company, 30 Main St., Brooklyn, N. Y.

The writer assumes that this more detailed explanation of his statements as contained in the article will answer conclusively the questions raised by the S.A.E. Spring Committee.

—HAROLD CARLSON
Chief Engineer
Lee Spring Company, Inc.

SWEDISH WIRE
Minimum Tensile Strength P.S.I.

Wire Diameter	A*	B	C
0.007	414,250	392,000	507,000
0.020	397,750	365,900	391,000
0.034	381,550	360,000	350,000
0.051	344,000	323,300	319,000
0.063	324,200	308,150	306,000
0.090	300,000	291,550	294,000

AMERICAN WIRE
Minimum Tensile Strength P.S.I.

Wire Diameter	D	E	A.S.T.M. A288–41
0.007	360,000	350,000	364,000
0.020	350,000	350,000	348,000
0.034	335,000	340,000	335,000
0.051	310,000	310,000	319,000
0.063	295,000	295,000	307,000
0.090	280,000	280,000	285,000

* Names of manufacturers listed as A, B, C, D, and E are not for publication but will be forwarded on request.

Gear Expert Learns New Design Process

To the Editor:

In reference to the letter by Mr. Trimbath in PRODUCT ENGINEERING for September (p. 535), pertaining to gear

teeth, my attention was called to this same question last week during a call at Michigan Tool Company. Until that time, we were not acquainted with the method developed by Michigan Tool. My statement was based on previous methods of crowning and did not consider any newer or special methods of correcting the error mentioned. We have produced a few crowned gears by lapping or grinding. Allow me to express my appreciation for this valuable information. —CHARLES G. PFEFFER
Wright Aeronautical Corp.

Editor's Note—Mr. Pfeffer was author of an article entitled "Gear Tooth Profiles" in PRODUCT ENGINEERING for June (p. 328), to which Mr. Trimbath referred in his letter.

Stevens' Solution Befuddles Readers

To the Editor:

The method used by Herbert H. Stevens in his article entitled "Angles in Space" (p. 392-394) July, PRODUCT ENGINEERING, to find the true size of the angle between two intersecting straight lines is, if I understand his solution, well known in descriptive geometry and is called the *method of rotation*. Mr. Stevens disguises the method by introducing certain preliminary steps into it which, so far as I can see, serve only to befuddle the reader. It may be, of course, that I don't understand what Mr. Stevens is driving at but if it should happen that I do, then I feel obliged to say that I see nothing unusual about Mr. Stevens' method of solving the problem except its utter lack of straight-forwardness.

To show that Mr. Stevens' solution of the problem is lacking in directness it need only be compared with a solution by the well-known rules of descriptive geometry. But I very respectfully warn any young reader of this journal who is unfamiliar with descriptive geometry that he will certainly be wasting his time if he tries to understand my explanation. —WILLIAM H. RASCHE
Virginia Polytechnic Institute

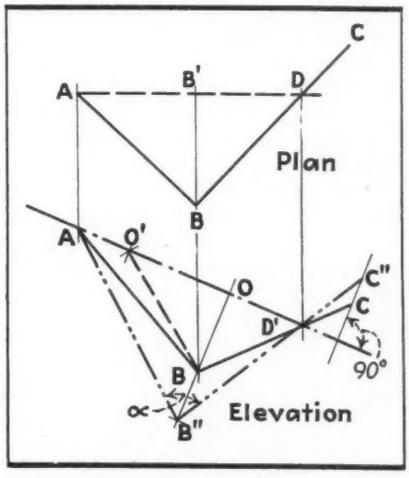
Editor's Note—The solution given by Professor Rasche is nearly identical to that submitted by Frederick G. Wilde. Since Mr. Wilde's construction shows also the lengths of the legs of the angle, it is given below.

To the Editor:

Since the graphical method of measuring space angles whose sides are oblique to the planes of all conventional orthographic views, which was described in PRODUCT ENGINEERING, July, by Herbert H. Stevens, seems unnecessarily complicated, I am offering the following method, which also permits measuring the true length of the sides of the angle.

Sides *AB* and *BC* of angle α are shown in elevation and plan views in the accompanying sketch. The procedure is as follows:

1. Draw a horizontal line *AD* intersecting line *BC* at *D* in the plan view.
2. Draw a vertical line through *D* intersecting *BC* at *D'* in the elevation view.
3. Draw line *AD'* in the elevation view.
4. Draw line *OB* perpendicular to *AD'* in the elevation view.
5. Locate *O'* on *AD'* at a distance *BB'* (plan view) from *O* (*OO'* = *BB'*).
6. Locate *B''* on line *OB* of elevation view at a distance *BO'* from *O* (*OB''* = *BO'*).
7. Draw lines *AB''* and *B''D'*. These lines are the sides of the true angle α.



The true length of side *AB* is *AB''*. To find the true length of *BC*:

8. Draw through *C* in the elevation view a line perpendicular to *AD'*.
9. Extend *B''D'* to the intersection *C*.

The line *B''C''* is the true length of the side *BC* of the angle.

The object of this construction is to turn the plane of the space angle so that it is parallel to one of the orthographic views, in this instance the elevation view. A group of lines that are parallel to the vertical plane can be drawn in the plane of the angle. Any of these lines appears in the plan view as a horizontal line. The line *AD* in the plan view, which is represented by *AD'* in the elevation view, is one of these lines. The plane of the angle is then turned around the line *AD'* into a vertical plane parallel to the elevation view. The point *B* turns around point *O*. The true distance *OB* is the hypotenuse of a right triangle, the other two sides being the distances between *B* and turning line *AD* and *AD'* in each view. This will be obvious if the triangle *ABD* is visualized in space.

When the plane of the angle *ABC* rotates around line *AD'*, the point *B* describes a circle which appears in the elevation view as line *OB*. When the plane is vertical, the point *B* is at *B''* and *OB''* is the true length of *OB*. Point *C* describes a circle which appears in the elevation view as a straight line through *C* perpendicular to line *AD'*. Since the points *B''* and *D'* on the rotated arm of the angle are already determined, the extension of the line to *C''* locates the point *C* after rotation. True lengths of *AB* and *BC* as well as the true angle between them are shown, therefore, by *AB''C''* in the elevation view. —FREDERICK G. WILDE

Can You Work This One?

H. E. SMITH

Solution to September problem—

Chestnuts and Peanuts

Each small boy had 12 (or 4) chestnuts. Each large boy had 12 peanuts. After the exchange each boy had 9 (or 3) chestnuts and 3 peanuts.

Let *b* equal the number of chestnuts each small boy had and *B* equal the number of peanuts each large boy had. Therefore, 9*b* equals the total number of chestnuts and 3*b* the total number of peanuts. Total number of boys is 12. Both 9*b* and 3*B* are divisible by 12, but 36 is the smallest number divisible by 3, 9 and 12. Therefore, with each small boy having four chestnuts and each large boy having 12 peanuts, they were divided up to give each three peanuts and three chestnuts.

This month's problem—

Marines and Natives

U. S. Marines, who always tell the truth, land on a tropical Pacific island populated by blacks who never tell the truth. A blind man asked a person on the island what color he was, but failed to hear the answer. Later he asked a second person what the first person said, and the second replied: "He says he is white." Later, the blind man asked a third person the color of the second and was told he was black. What color was the third man?

News and Summaries

Magnesium Use Broadened by New Welding Process

THE DESIGNER'S DREAM of unlimited use of magnesium in aircraft construction has been brought a step nearer reality by development of a new arc welding process.

Perfected by Northrop Aircraft, Inc., the new process is known as "heliarc" welding. It discharges a jet of helium gas on the molten metal, preventing oxidation. No flux is used, thereby eliminating the possibility of entrapping flux which would promote corrosion in the weld.

If the process is adopted on a wide scale, it could:

1. Eliminate thousands of rivets per plane, saving material and man-hours and improving flight performance.

2. Reduce or eliminate the tremendous drain on aluminum supplies which is currently one of the principal problems in aircraft production.

3. Reduce the heavy drain on the electric power supply.

Heretofore, magnesium has been limited in aircraft use despite the weight savings it offers because it is harder to work than aluminum and because knowledge of its "workability" was limited.

"This new method of arc welding has made possible the use of a new material for aircraft construction which lies in inexhaustible quantities off our shores, and it has simplified methods of construction that will speed plane output," Thomas E. Piper, Northrop process engineer, told the American Welding Society in announcing the process.

Since magnesium is 35 per cent lighter than aluminum, which now is used for most wing and fuselage skins, it can be applied in gages sufficiently thicker to allow welding. The resultant elimination of rivet heads and wrinkles would reduce "parasite drag," which in turn would free engine power formerly used to overcome that drag for more efficient use.

The availability of magnesium, which may be recovered from sea water, brine wells, rocks and ores, also enhances the value of the new welding process. The biggest single bottleneck in the rapid expansion to which we subjected our aircraft production facilities two years ago was aluminum, and in finished form for use in planes, it is still dismally short. Although magnesium alloys are currently more expensive than comparable aluminum alloys, the price will be lowered as new production facilities move into the market.

Another advantage of any process which enables wide use of magnesium alloys in aircraft is in the electric power savings which will result from substitution for aluminum. Currently, 24,000 kwh. are required to produce a ton of aluminum from bauxite. Only 18,300 kwh. are required to produce a ton of magnesium, which has 54 per cent more volume.

Piper declared that, contrary to popular belief, magnesium alloys are not inflammable when properly processed and actually are more resistant to direct flame than aluminum alloys.

Magnesium alloys not only are lighter than aluminum alloys, but their strength-weight ratios are comparable to those of aluminum alloys and they possess stiffness and rigidity properties unavailable in other alloys.

Welding rods of the same alloy as the parent metal provide weld beads which have better corrosion-resistant properties than the parent metal. The bead, however, appears to be cathodic to adjoining metal, and this causes minor pitting of the original metal adjacent to the weld under severe corrosive conditions. Beads show extremely fine grains, and there is practically no grain enlargement adjacent to the bead.

"Heliarc" welding has been proved successful in joining magnesium, stainless steel, brass, Inconel, Monel and some carbon steel alloys. Best installation for it is a conventional arc welding machine with a direct current generator capable of 150 amperes. Helium gas must be fairly pure. Any type of joint commonly used for welding ferrous metals may be used on magnesium and stainless steel under this process.

Hemphill Institute Furnishes Laboratory

A STAFF OF TECHNICIANS trained in several fields, laboratory equipment and shop facilities will be made available without charge to "men with ideas and inventions" which might aid the nation's war program under the new Ralph Hemphill Research Foundation.

The foundation was organized by Ralph Hemphill as part of the enlarged Hemphill Institute of Technology at Los Angeles. The Institute is training Army, Navy, and Coastguard personnel in diesel engine operation, maintenance and overhaul at schools in Los Angeles, Memphis, New York and Chicago.

Goodyear Sponsors Drive To Conserve Rubber

DEEMING RUBBER CONSERVATION as important in the factory as on the highway, the Goodyear Tire and Rubber Company, of Akron, O., has established a "Conservation Roll of Honor," by which it affords recognition to those industries which participate in a program designed to lengthen as much as possible the life of equipment containing rubber.

The program includes an illustrated talk by a company representative and distribution of manuals which give instruction in general industrial rubber conservation and in repair of belts. The program is presented first to executives, then to maintenance and other employees. It is offered without charge as a war measure.

Certificates bearing the company name are distributed to participating organizations.

New Test Shows Flaws In Heat-Treated Steel

WESTINGHOUSE RESEARCH LABORATORIES has perfected a simple magnetic method for detecting flaws in heat-treated parts. The test is fast and accurate, and can be performed without touching the specimen.

The process is based on the fact that even though the external magnetic field of a symmetrical piece of steel which has been properly heat-treated and magnetized is uniform, any defect, such as a hard or soft spot, changes the specimen's magnetic pattern. Thus in the test, the heat-treated piece is demagnetized completely, then rotated at high speed and strongly magnetized. Then the field is explored with an elec-

tro-magnet consisting of an alloy bar surrounded by a coil. Variations of the magnetic field induce a voltage in the coil which is amplified and described visually by an oscilloscope. When the test piece is rotated synchronously with the cathode-ray sweep, a uniform field is traced on the tube screen in the form of a luminous straight line. Faults show up as dips in the oscilloscope trace. A second trace on the tube screen acts as a reference line and carries 12 index points, corresponding to 30 deg. angles around the test piece. Thus a fault can be located within a few degrees on the periphery.

To this test may be added a relay system to give an audible signal when a fault is found, or to operate automatic machinery which will throw out defective pieces.

Use of Sewage Gas Saves Fuel, Cuts Costs

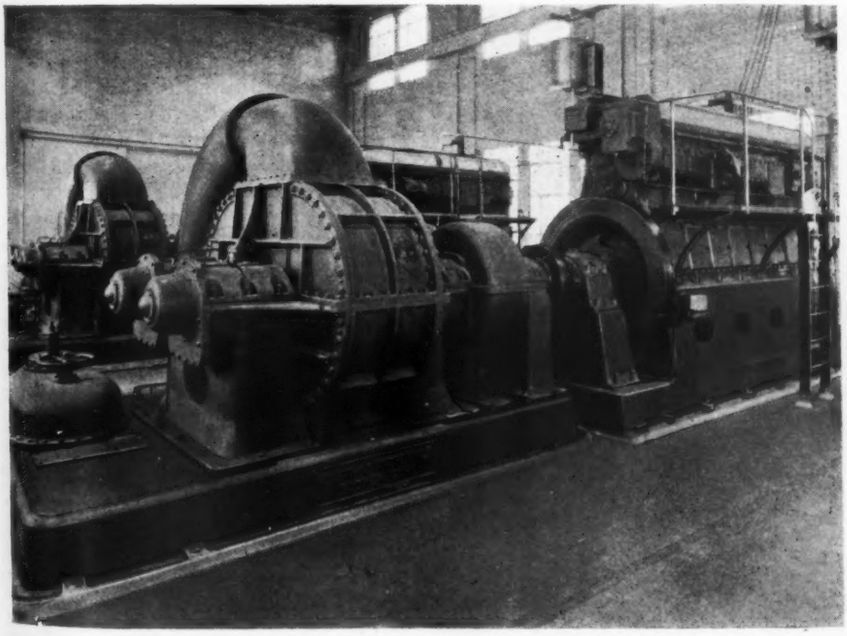
SEWAGE GAS which normally is burned as waste may be utilized as fuel at a considerable saving of natural or manufactured gas for war industries.

G. E. Flower, superintendent of a Cleveland municipal sewage disposal plant, in which two Cooper-Bessemer engines are operated on sewage gas at a saving of approximately $10,000 a year, says the substitute fuel "compares favorably with other gases," and adds that the efficiency of the engines would be the same no matter whether sewage or natural gas were used.

No special accessories are required to operate the engines on sewage gas, according to B. B. Williams, president of the Cooper-Bessemer Corporation, who explains that the power plants were designed for operation as straight diesels or on gas. Simple changes in the power-cylinder liner and pistons and installation of the ignition system required by the type of fuel to be used is all that is necessary to transfer from one fuel to the other. No changes need be made in the cylinder head.

The engines which develop 420 hp. at 420 r.p.m., are standard 8-cylinder units with 11½ in. bore and 13½ in. stroke. Flower described the gas as having a heating value of 600 to 700 Btu. per cu. ft., containing 65 percent methane, 30 percent carbon dioxide and 5 percent nitrogen. Hydrogen sulphide content is practically zero. The gas does not require special processing before use as fuel.

Williams asserted that every average-size sewage plant in the country could heat sludge in digestion tanks and burn it, heat its buildings, and generate power for lighting and machine operation by utilizing available sewage gas. In addition, where the supply is greater than the plant might economically use, the gas may be distributed to industrial plants. Both of these processes would save considerable natural or manufactured gas for war or other industries.



These Cooper-Bessemer diesels at Cleveland's southerly sewage treatment works use sewage gas for fuel, saving the city $10,000 a year in operating costs and releasing large quantities of natural gas for area defense plants. Experts say sewage gas is as good a fuel as any other, and point out that municipal installations such as this can obtain most of their fuel from sewage gas.

Colleges Add Electronics, Communications Courses

COURSES IN ELECTRONICS and communications are taking an increasingly large part of the time in a majority of colleges and universities offering instruction in electrical engineering, according to a survey by *Electronics*, published in its September 1942 issue.

Under the survey, heads of electrical engineering departments in every college or university offering degrees in that field were asked to indicate what courses have been added to their own or to physics department curricula during the past year and to outline those electronics and communications courses now being offered. These significant facts were developed:

1. Majority of electrical engineering departments are increasing or have increased their communication and electronics courses.
2. More than 40 institutions have conducted or are offering communications courses under the Engineering, Science and Management War Training program.
3. At least some of the smaller colleges are facing difficulties in providing sufficient staff for instructions.
4. Some of the larger institutions are busy with imposing research programs and with training of scientists and officers for work in these fields.

According to the survey, a few schools have made virtually no changes in their curricula for several years, and offer only the slightest instruction in electronics or communications. On the other hand, the electrical engineering department of the University of Washington is devoting practically all its energy to training men in electronics.

Much of the emphasis on these subjects which has been forthcoming among American colleges and universities recently is placed on communication subjects in the extremely high-frequency spectrum. A number of the new courses have been aimed at men directly or indirectly working for the armed services.

Development of new tubes and ultra-high-frequency technique are major technical contributions to the electronics field arising out of the present war, *Electronics* also pointed out. The tremendous activity in the application of electron tube devices, as a result of the vast radio communication needs of the armed services, the development of many new electronic devices for direction finding, detection and protection purposes, and the training of great numbers of persons in the technical aspects of electronics gives every indi-

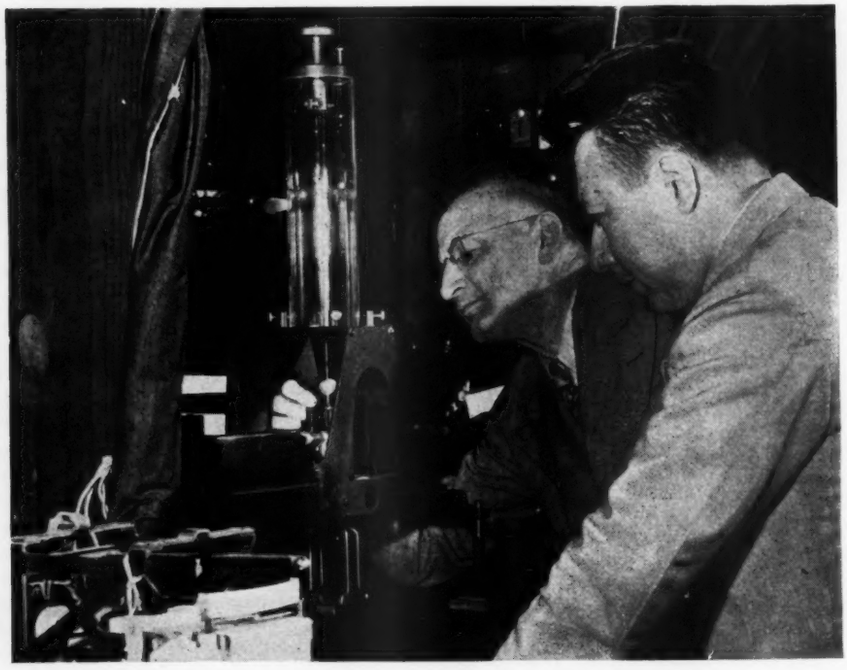
cation that post-war developments will produce a new electronics industry comparable to that of the broadcast industry which developed out of research undertaken during the first World War.

Photocell, Matching Grids Give Accurate Creep Data

A PHOTOCELL which measures the variations in light passing between parallel lines on two grids is saving General Electric Company research men long hours at the microscope and is turning in more accurate data on metal flow than humans could hope to compile.

A new device employs a weighted wire strand of the material under examination. The specimen is enclosed in a glass cylinder, which may be filled with nitrogen to prevent rust, and heated to a temperature as high as 2,000 deg. F. Attached to its free end is a grid on which numerous lines 1/250th of an inch wide and that far apart have been etched. The grid hangs close to a similar, stationary grid, and an enlarged image of each is cast on a photocell which converts light into electricity. Changes in the current are recorded in ink by a meter which uses electronic tubes. The device allows accurate measurements of increases as small as 1/10,000th of an inch in the length of the wire, since the grids are aligned at the start of the test. As the specimen creeps, the grids move out of line, blocking off light from the cell and lowering the current it transmits. The principle may be seen by aligning teeth of two combs held side by side to represent the grids.

J. T. Mireles Malpica, of the G-E General Engineering Laboratory, devised the method. Previously, sample bars were heated to temperatures ranging from 800 to 1,400 deg. F. and studied through a microscope while they stretched as much as one-half of one percent an hour. Such tests sometimes took months to complete.



Dr. Saul Dushman, left, and J. T. Mireles Malpica, are adjusting the device invented by the latter to measure "creep" in metals. The device was perfected in General Electric Research laboratories. It compiles more accurate data than was possible under earlier test methods, which required an attendant to spend long periods at a microscope.

Meetings

National Metal Exposition—"War Production Edition," Public Auditorium, Cleveland, Ohio, Oct. 12-16. W. H. Eisenman, Managing Director, 7016 Euclid Ave., Cleveland, Ohio.

American Society for Metals—National Metal Exposition and annual meeting, Cleveland, Ohio, Oct. 12-16. W. H. Eisenman, Managing Director, 7016 Euclid Ave., Cleveland, Ohio.

American Welding Society — National Metal Exposition and annual meeting, Oct. 12, Cleveland, Ohio.

American Society of Mechanical Engineers—Fall meeting, Hotel Sagamore, Rochester, N. Y., Oct. 12-14.

Acid-Resistant Enamel Defies Long Exposure

EXPERIMENTS designed to show the value of various types of porcelain enamel on architectural units showed glossy, acid-resistant compositions to be in excellent condition after a year's exposure to the elements, the National Bureau of Standards reported.

Non-acid resistant finishes showed signs of weathering and mat enamels appeared to be unsuited for architectural use in which appearance plays any important part since they fade and are difficult to clean. In addition, some colored, non-acid resistant enamels faded because of tiny surface pits probably caused by such acid-forming gases as carbon dioxide and sulphur dioxide.

The test, which involves the use of 864 one-foot-square panels and a similar number of 4x6 in. laboratory specimens, was undertaken to provide data on these materials which are finding increasing use with the shortage of zinc and tin for galvanized roofing and siding. Panels are erected for weathering tests at Washington, D. C., Atlantic City, N. J., St. Louis, Mo., and Lakeland, Fla.

Shepherd to be Given Albert Sauveur Award

PROFESSIONAL RECOGNITION for his research on tool steel comes to Benjamin F. Shepherd, chief metallurgist of the Ingersoll-Rand Company, at the annual dinner of the American Society for Metals October 15 at Cleveland.

Shepherd will be awarded the Albert Sauveur Achievement Award for his development of the Shepherd fracture standards for tool steels and the penetration-fracture test. These developments grew out of his search for the tool steel which could best stand up under the bitter pounding to which air drills are subjected.

Shepherd found that the ability of a given piece of steel to withstand punishment depends on fineness of grain structure and the depth to which it penetrates. His research contributed considerably to the present concept of hardenability and instigated much of the experimentation on which war production is based.

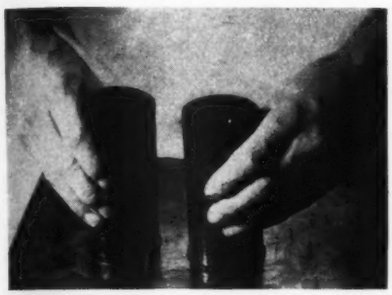
Do You Know That—

SILVER-FACED STEEL, highly resistant to galling when in sliding contact with steel, is used in aircraft engine bearings subject to high specific loading. (16)

New Materials and Parts

Saran Pipe Saves Metal

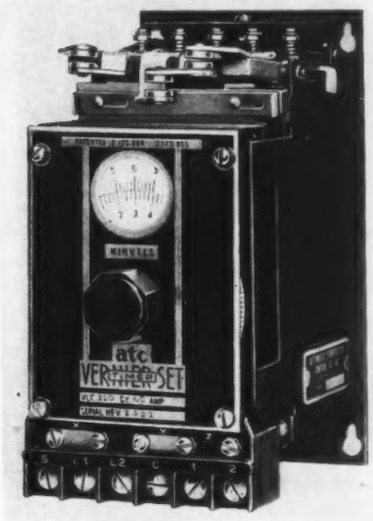
Saran pipe is made of the same tough, non-freezing plastic as Saran tubing. It furnishes excellent heat resistance up to 175 deg. F, and saves considerably in weight and metal. The plastic is odorless, tasteless, non-toxic, and is unaffected by water. Only a few solvents show any adverse effect on it. It will neither burn nor scale, may be welded, heated and bent, cut with a wood or hack saw and threaded with ordinary iron pipe dies. Except for



standard flanges, no fittings are now available, although molds for them are now being constructed. Available in same dimensions as extra strong steel pipe of 2 in. outside dia. Illustration shows how sections may be welded by placing ends on plate heated to 350–400 deg. F. until molten material appears, then pressing ends together firmly and allowing 10 sec. for cooling. Resultant weld has greater joint strength than pipe. Dow Chemical Co., Midland, Mich.

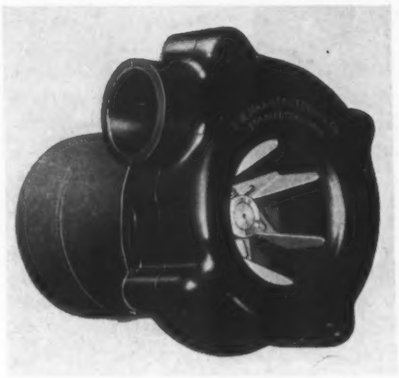
Improved Timer Has One-Piece Terminal

Improvements on vernier set timers include a one-piece, molded bakelite terminal block, leaf-spring contact, independent wiring for timer and load circuits and a special wiring throughout. Illustration shows the new set, designated Series 2800. The new terminal block accommodates all exterior wiring on clearly-marked screw post terminals and bridge positions for easy selection of desired arrangement. The new contact insures positive make-break action, and timer and load circuits, now wired independently, may be wired together by use of an external jumper between designated terminals. Available in two types, with normal clutch action for re-setting after power failure and with reverse clutch action for non-resetting. Dials are available in 12 sizes from 15 sec. to 60 hr. Standard units operate from 110 and 220 volts, 25, 50, or 60 cycles. Load contacts are rated to carry 25 amp. at 110 volts, a.c. non-inductive, and frequently eliminate use of intermediate contactors or relays. Automatic Temperature Control Co., Inc., Philadelphia, Pa.



Size, Efficiency Allow Many Uses for Blower

Compact and efficient, this blower which was designed to meet needs presented by restricted space and high temperature encountered in airborne electronic units, may be put to a wide variety of other uses. Universal mounting is possible by means of four screws which may be used as bracket supports. Its capacity is 60 cfm. at 7,500 rpm.,



and any 1/100 hp. motor operating on 6, 12, 24 or 28 volts direct current or 110 volts, 60 cycles or 115 volts, 400 cycles alternating current is suggested to drive it. A plate for mounting the motor is provided. Housing is of high-impact plastic capable of withstanding temperatures up to 375 deg. F. Wheel is turbo type, 2 in. dia., mounted on a ¼ in. shaft. Two holding screws in the hub are set at 90 deg. angles. L-R Mfg. Co., Torrington, Conn.

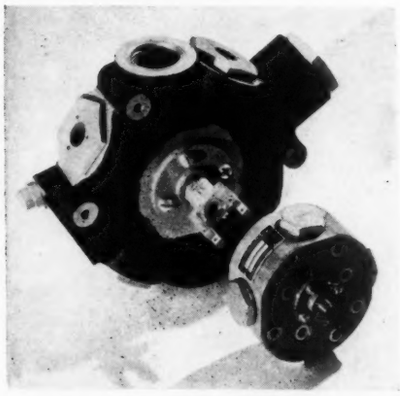
Gage Measures Wear To 15 Millionths In.

Accurate measurements of wear on metallic surfaces may be had with the new McKee wear gage whose range is from 14 ten-thousandths to 15 millionths of an inch. Measurements may be made

on inside surfaces of cylinders above a minimum diameter of 2$\frac{7}{32}$ in., on flat surfaces, on outer surfaces of cylinders down to $\frac{3}{32}$ in. dia. and on spheres down to $\frac{1}{4}$ in. dia. Measurements are taken by means of a diamond-shaped pyramidal indentation on the surface under test. Its dimensions are known. After wear, a second measurement of the base of the indentation will show the amount of material which has been removed. The instrument can be used to ascertain when a predetermined amount of wear has taken place and to show the amount of metal removed between given limits. Four parts, an indenter, a measuring microscope, a cylinder indentation locater and a polishing templet, are supplied, as well as a multiplying factor for converting microscope readings to indentation depths and a correction formula and table for curved surface calculations. American Instrument Co., Silver Spring, Md.

Hydraulic Selector Valve Saves Space, Weight

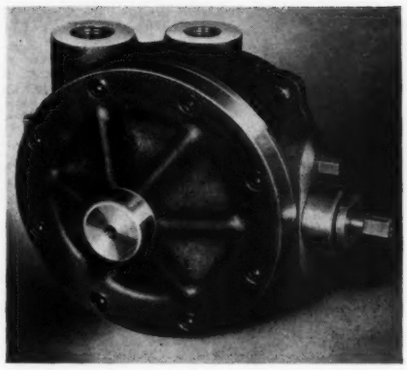
This four-way, hydraulic selector valve combines top performance with minimum weight and bulk. Plastic poppets weigh one-sixteenth as much as the steel they displace and give quiet operation. Characteristic radial design reduces bulk. Pressure drop is low in



these latest $\frac{3}{8}$ and $\frac{3}{4}$-in. additions to the line which now numbers nine models and covers every tube size and style from $\frac{1}{4}$ to $\frac{3}{4}$ in. Bendix Aviation, Ltd., North Hollywood, Calif.

Standard Mount Used On Hydra-Motive Pump

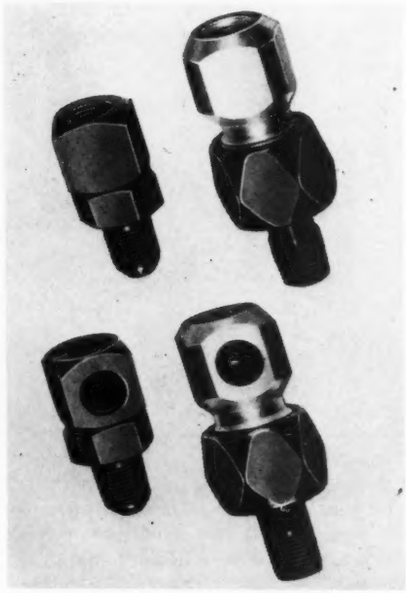
Furnished with standard mounting, Hydra-Motive vane-type pumps may be used as replacement or new equipment for jobs requiring a variable rate of flow between zero and 4 g.p.m. The device operates at 1,000 lb. per sq. in. Originally designed for exclusive use



with an automatic machine tool control, the pump may now be had for general use with heavier section reinforcing webs and a conical cover plate for greater shock resistance. Two edges as well as the stator side of the balanced vanes are bevelled for reduction of wear, elimination of over-heating and increased operating efficiency. Stator is a split ring to permit maximum selection of adjustment. Mounting is the type considered standard by most manufacturers. Hydra-Motive, Inc., Detroit, Mich.

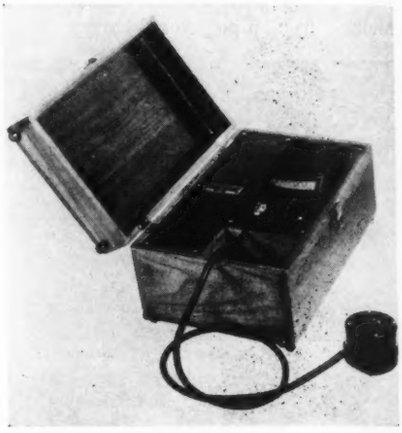
Swivels Hold Lines On Moving Elements

Straight or 90-deg. swivels with or without ball bearings allow oil, grease, air or other lines to be connected to moving elements. Standard swivels employ ball bearings which allow them to turn freely at any pressure. The stem and nut on which the bearing turns is hardened to minimize wear. Light-duty swivels, intended for use only where space limitations forbid use of the heavier assemblies, have no bearings. Illustration shows a straight and a 90-deg. sample of each model. Standard swivels are available in $\frac{1}{8}$, $\frac{1}{4}$, $\frac{3}{8}$, $\frac{1}{2}$, $\frac{3}{4}$ and 1 in. pipe sizes. Light-duty swivels are available only in $\frac{1}{8}$ and $\frac{1}{4}$ in. sizes. Any may be had with left-hand thread on special order. Trabon Engineering Corp., Cleveland, Ohio.



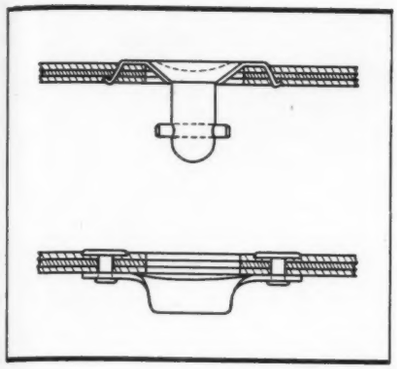
Reflection Meter Aids In Specifying Material

Designers may use portable photoelectric reflection meters to specify the color and surface conditions of their materials. Two instruments, one of which operates from dry cells, the other from electric current, are available. The search unit, which contains the light source and the photocell, is connected to the instrument by a flexible cord which allows the user to move it around on the sample. Light passes from the search unit through a color filter and an aperture in the photocell to the sample whence it is reflected back to the cell. Readings may be taken from a taut-wire suspension galvanomter whose indicator needle is set on 100 for the standard in terms of which measurements are to be taken. Photovolt Corp., 95 Madison Ave., New York, N. Y.



Curved Prongs Give Fastener Extra Grip

Airloc cowling fasteners may be applied to plywood after only four holes have been drilled. The stud assembly contains a pronged, self-piercing washer which covers a comparatively large area and is attachable with simple press tools. Prongs on the washer are curved to cut back into the wood after penetration and hold securely. The spring requires the same center hole as the stud and two additional holes for eyelets or rivets. Eyelet flanges or



washers may be pressed into the wood, or countersunk to a depth of 0.020 in. Illustration shows stud mounted above spring in position for fastening. United-Carr Fastener Corp., Cambridge, Mass.

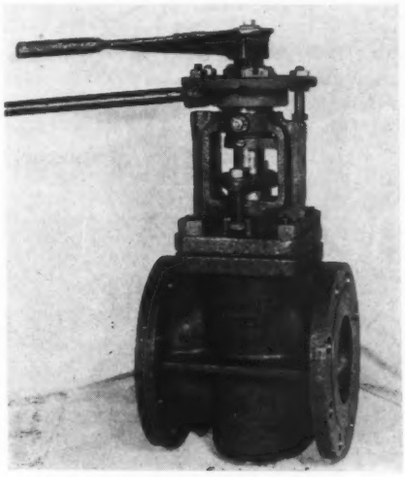
Solves Angle Attachments

New angle anchor Speed Nuts have been developed to solve the problem of right angle attachments to which access is from one side only. The development provides a double-locking, spring tension grip in a fastener suited for attachment of junction or switch box covers, fairings and many other angular fittings. The device combines a standard U type Speed Nut with an angle bracket. Available for use with 6 and

8-32 machine screws and 4, 6 and 8Z sheet metal screws. The angle irons are available in 86, 90 and 94-deg. angles. Tinnerman Products, Inc., Cleveland, Ohio.

Interchangeable Valve Retains Old Features

"Lever-Seald" plug valves, made of semi-steel or steel for working pressures of 150 lb. per sq. in., have the same face-to-face dimensions as wedgegate valves of corresponding size, and thus may be interchanged with wedgegate valves without pipe changes. The new model illustrated here incorporates traditional "quarter-turn" operation and powerful leverage which assures positive and easy opening or closing under all conditions. Available in sizes from 1½ to 10 in. Homestead Valve Mfg. Co., Coraopolis, Pa.

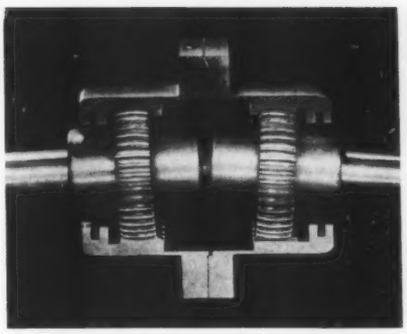


Laminated Contact Saves Vital Metals

New laminated contacts made of Gibsiloy surfaces mounted on base metal save both costs and vital materials. Gibsiloy surfaces are produced by special processing of metal powders which normally do not alloy naturally. Mounted on metal bases of cheaper, non-vital material, they meet the diversified needs of many types of equipment. Available in inlay or overlay types, with Gibsiloy, silver or other precious metal surfaces. Gibson Electric Co., Pittsburgh, Pa.

New Coupling Design Uses Spherical Gears

The Barcus coupling accommodates driving and driven shafts as much as 6 deg. out of alignment through use of spherical and internal gears which are allowed sufficient play to compensate for the misalignment. Illustration shows shafts each of which are 3 deg. out of line. Both shafts are connected to hubs of generated gears each cut on a true central segment of a sphere. Teeth surfaces are of constant width throughout their length. Meshing with stub teeth of the housing, they produce a smooth ball action which helps reduce friction and pressure on shaft bearings. The specially designed spherical gear is in full mesh on pitch line with the internal gear at all times, giving minimum back



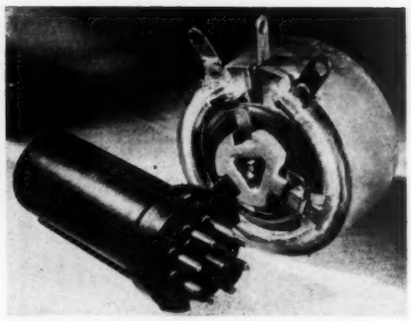
lash. Available in four sizes whose capacities range from 18.3 to 128.1 hp. at 100 r.p.m. Barcus Engineering Co., Baltimore, Md.

New Steel Provides Extreme Toughness

A water-hardening tool steel known as "Jessop RT" is available for jobs where extreme toughness is the first prerequisite. RT has a breaking strength of 323,000 lb. per sq. in., and ductility enough to allow a 3.5 percent elongation in 2 in. In small sizes, the steel will harden throughout. Larger sizes will have a hard case and a tough core. A 1½ in. piece will have a fine-grained case as deep as ¼ in., with a hardness of C 61/63 Rockwell. Illustration shows the material as cutter wheel in a heavy-duty pipe cutter. Jessop Steel Co., Washington, Pa.

Rheostat Size Doubled

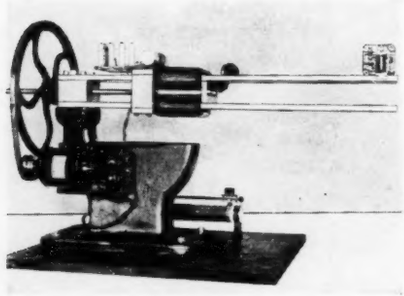
A new 50-watt rheostat, available in resistance values up to and including 10,000 ohms, is similar in design to a successful 25-watt unit introduced two years ago. Selected resistance wire



wound on an insulated metal core distributes the heat at intermediate rotational settings. Resistance element is firmly embedded in a ceramic housing, and a graphite copper contact shoe rides the collector ring and winding, furnishing two positive sliding contacts. Pressure is provided by a helical spring concentrically mounted about a shaft whose action is distributed evenly by a tripod-type contact carrier. A center ceramic insulator separates the shaft and the contact. The rheostat is shown beside a radio tube. Clarostat Mfg. Co., Brooklyn, N. Y.

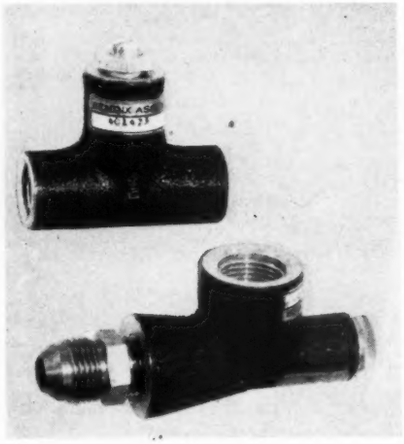
Testing Device Uses Tuning Fork Principle

This device for testing lightweight equipment under conditions of vibration prevents shock or vibration from being transmitted through the building. This application of the tuning fork principle is novel, and since vibrations are balanced, none are transmitted to the work bench or floor. Thus, several machines may be used in the same room at the same time. The vibration system contains no cranks, gears or bearings to be shaken, loose or otherwise affect testing conditions. Tests may be conducted in any plane and the angle at which the specimen is held may be changed during the test. Thus, two similar specimens may be tested simultaneously under different conditions. Amplitude and frequency are variable in test. Maximum test conditions require 75 watts. Kurman Electric Co., Inc., 241 Lafayette St., New York, N. Y.



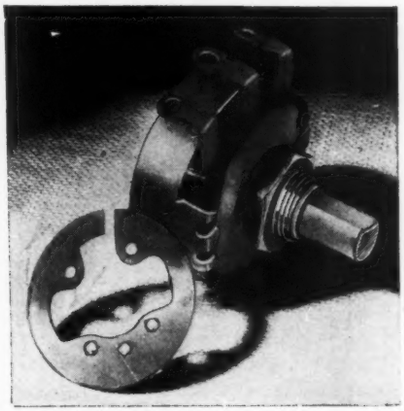
Restrictor Valves Control Oil Flow

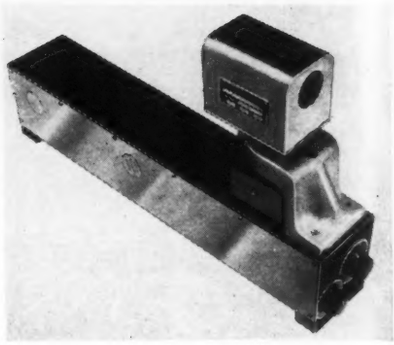
Rate of flow in either or both directions of a hydraulic system may be retarded by these adjustable restrictor valves, which were designed primarily for aircraft use. Both types are quickly adjustable under pressure to any point from no flow to full flow of ¼ in. tubing. Needle-type valves provide an annular flow at the point of restriction and reduce the possibility of stoppage by foreign matter. Illustrated are two-way (above) and one-way valves. Bendix Aviation Ltd., North Hollywood, Calif.



Wear of Non-Wire Element Increased By New Coating

A new, stabilized potentiometer element, composed of a resistant coating on a phenolic resin base is claimed to be virtually on a par with wire-wound units as regards resistance permanence, immunity to climatic conditions and wearing qualities. The new element is chemically treated during processing to eliminate any further changes in composition, and is heat-treated to stabilize temperature and humidity characteristics. Clarostat Mfg. Co., Brooklyn, N. Y.



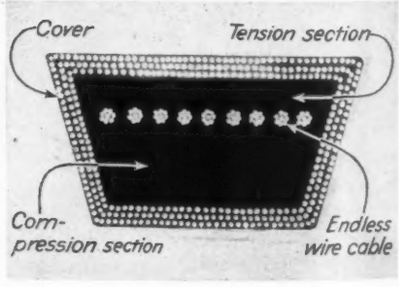


Dual Scanner Operates On Any Kind of Material

This self-contained Dual Scanner operates with transmitted or reflected light on transparent, semi-opaque or opaque material. Its operating speed is subject only to mechanical limitations of auxiliary equipment. The Dual Scanner operates on 110 volts, 60 cycles a.c. with telephone relays. Its minimum impulse time is 0.005 sec. Sensitively is as low as 2 percent for transmitted light or 4 percent for reflected light. Source is a 6-volt, 21 cp. lamp. United Cinephone Corp., Torrington, Conn.

Steel Wire Toughens New Belt for Tanks

Steel wire imbedded in V-belts, a new solution to the problem of providing adequate belts for tanks and armored vehicles, may be employed on other installations demanding extra strength and heat-resisting ability. The new belts, now being manufactured in volume for military needs, provide the increased strength and heat resistance with considerably less stretch. These qualities are vital in tanks and armored vehicles in which belts are inaccessible and in whose engine chambers high temperatures develop. Since these engines, due to their armor plate protection have less efficient means of dispersing this heat than do conventional power plants, belts must be able to hold up under severe conditions. Illustration shows cross-section of the new belt with wire imbedded near the top. Goodyear Tire & Rubber Co., Akron, Ohio.



Books and Bulletins

Plastics

J. H. DuBois—295 *pages,* 5¾ x 8½ *in. Brown clothboard covers. Published by American Technical Society, Drexel Ave. at 58th St., Chicago, Ill. Price* $3.

The publishers call this book "a simplified presentation of the manufacture and use of the important plastic materials and products with tables of their properties and the basic design information required by engineers and designers."

That is a good description. All complicated chemistry is eliminated, and the design, selection and production considerations could hardly be made more simple. The author groups plastic materials into general types, and covers each type in a separate chapter, giving general description, discussion and tables of properties, and unusually complete data on machining, finishing and assembly of parts made from that material.

Other chapters cover the molding processes and mold making. A separate chapter on finishing and decorating supplements the data given for each material. Of specific interest to design engineers are two chapters on selection of material and design of molded products.

Throughout the book, sketches and illustrations bolster the presentation immensely. A complete cross-index and heavy black headlines in the text make "Plastics" a good reference volume.

Patents and Industrial Progress

George E. Folk—393 *pages,* 5¾ x 8½ *in. Blue clothboard covers. Illustrated and indexed. Published by Harper and Brothers, 49 E. 33rd St., New York, N. Y. Price* $3.

The author, special patent adviser to the National Association of Manufacturers, attacks the contention that patent rights are in conflict with anti-trust laws. He analyzes recommendations for patent reform, and discusses the situations existing in several vital war products allegedly restricted by patent abuse. Folk differentiates between cartels and legal patent licensing agreements, and discusses the role of patents in the exchange of scientific knowledge between nations in times of peace. Illustrations include charts, graphs and tables in support of his thesis that any illegal trade restrictions in which patents figure may be handled by existing anti-trust law. Foreword by Robert L. Lund, chairman of N.A.M.'s Patents and Research Committee.

Engineering Mechanics

Frank L. Brown—500 *pages,* 5½ x 9 *in. Blue clothboard covers. Published by John Wiley & Sons, Inc., 440 Fourth Ave., New York. Price* $4.

The second edition of "Engineering Mechanics," designed primarily as a textbook for undergraduate engineering students, has undergone changes in the manner of presentation, particularly to put greater emphasis on the solution of problems expressed in words rather than symbols fitting memorized formulas. A large portion of the problems of the first edition have been replaced and the total number increased. The illustrations are all new. The author has tried to give enough explanation and amplification of each subject to enable the student to progress understandingly with a minimum of outside aid.

The book is divided into two parts, the first devoted to statistics and the second to kinematics and kinetics, each covering the usual subjects to be found in most textbooks on this subject.

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Machine Tool Electrical Standards

15 *pages, paper covers,* 8x11 *in. Published by the American Standards Association, 29 W. 39th St., New York, N. Y. Price 40 cents.*

Written and symbolic standards for manufacturers of machine tools, as drawn up by the emergency technical committee of the A.S.A., and the National Machine Tool Builders' Association committee on electrical problems, are presented in this bulletin. Standards are set up for diagrams, controls, motors, wiring, grounding and electrical accessories as well as general standards applicable to the problems posed by specifying equipment for machine tools. The bulletin also contains a page of references whence these standards were drawn.

Code of Minimum Requirements For Instruction of Welding Operators

68 *pages, paper covers,* 6x9 *in. Published by the American Welding Society, 33 W. 39th St., New York, N. Y. Price 50 cents.*

This bulletin is a revision and expansion of a proposed code published in 1941. It was expanded particularly with respect to supplementary material contained in the appendixes as suggestions for organization of welding courses. Principal sections of the code stipulate standards for school equipment and facilities; qualifications and duties of instructors; welding practice instruction, welding theory instruction and final tests. The manual also contains the following appendixes: suggested accessory school equipment; recommended design of positioning equipment; recommended designs and applications of testing apparatus; recommended safety rules for students; welding electrodes; suggested arc-welding exercises; suggested student progress charts; recommended form for record cards, and a selected, annotated bibliography of publications relating to welding instruction.

Plastics From Agricultural Materials

O. R. Sweeney and L. K. Arnold—*Bulletin No. 154 by the Iowa Engineering Experiment Station, Iowa State College, Ames, Iowa. 42 pages, paper covers, 6x9 in. Published by the Iowa State College of Agriculture and Mechanic Arts, Ames, Iowa.*

Development of numerous plastics from such agricultural products as soybeans and corncobs with various fillers and by various processes is explained in detail in this illustrated manual. Processes for each type of plastic are described, many of them illustrated with pictures of equipment, tables or diagrams. Comment on each major section includes conclusions on the value and industrial possibilities of plastics experimented with. The bulletin also contains a bibliography.

Letter Symbols for Mechanics of Solid Bodies

6 *pages, paper covers,* 8x10½ *in. Published by the American Society of Mechanical Engineers, 29 W. 39th St., New York, N. Y. Price 25 cents.*

General principles of letter-symbol standardization and a list of 68 symbols are contained in this bulletin drawn up by the A.S.M.E.'s sectional committee on letter symbols and abbreviations for science and engineering. It was approved by the American Standards Association.

Fiberglas Standards

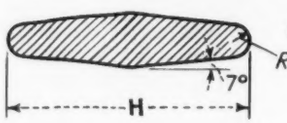
Standard H9.2.1, Fiberglas Electrical Insulation; and Standard H9.3.1, Fiberglas Insulations for Electrical Equipment. Published by Owens-Corning Fiberglas Corporation, Toledo, Ohio.

In Standard H9.2.1 are set forth in text and charts the numerous forms of fiber glass insulation materials available with their electrical characteristics and properties. Standard H9.3.1 contains application suggestions for the use of fiber glass in insulating electrical wires, also information as to how it can be used in cable construction. Included also are data on how to insulate motor, generator and transformer coils. Both bulletins are well illustrated and contain much information of value to designers of electrical units and apparatus.

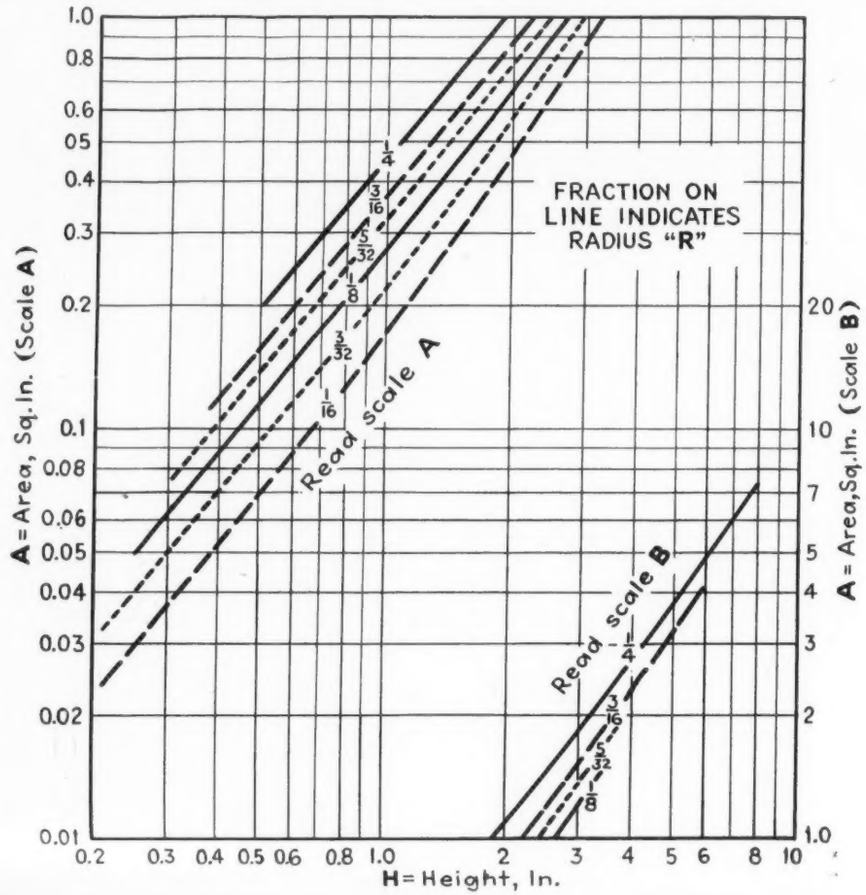
FORGING DESIGN DATA — AREAS OF FORGING SECTIONS

O. A. WHEELON
Methods Analysis Engineer, Douglas Aircraft Company, Inc.

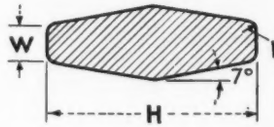
Round Top Flange Section



$A = 0.0614\,H^2 + 1.76944\,HR - 0.64168\,R^2$

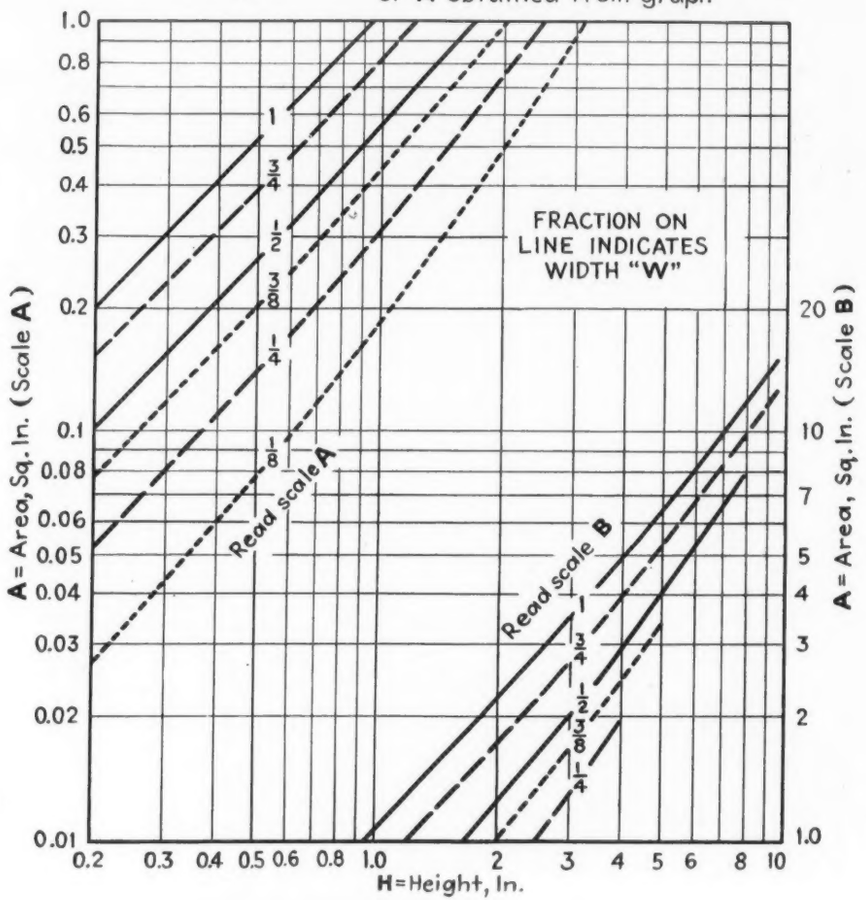


Flat Top Flange Section



$A = 0.0614\,H^2 + HW - 0.6417\,R^2$

Curves plotted for first two terms only; subtract $0.6417\,R^2$ from value of A obtained from graph



FORGING DESIGN DATA — MOMENT OF INERTIA ABOUT X-X AXIS

O. A. WHEELON

FORGING DESIGN DATA — MOMENT OF INERTIA ABOUT X-X AXIS

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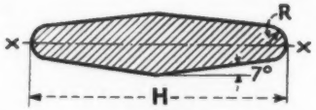
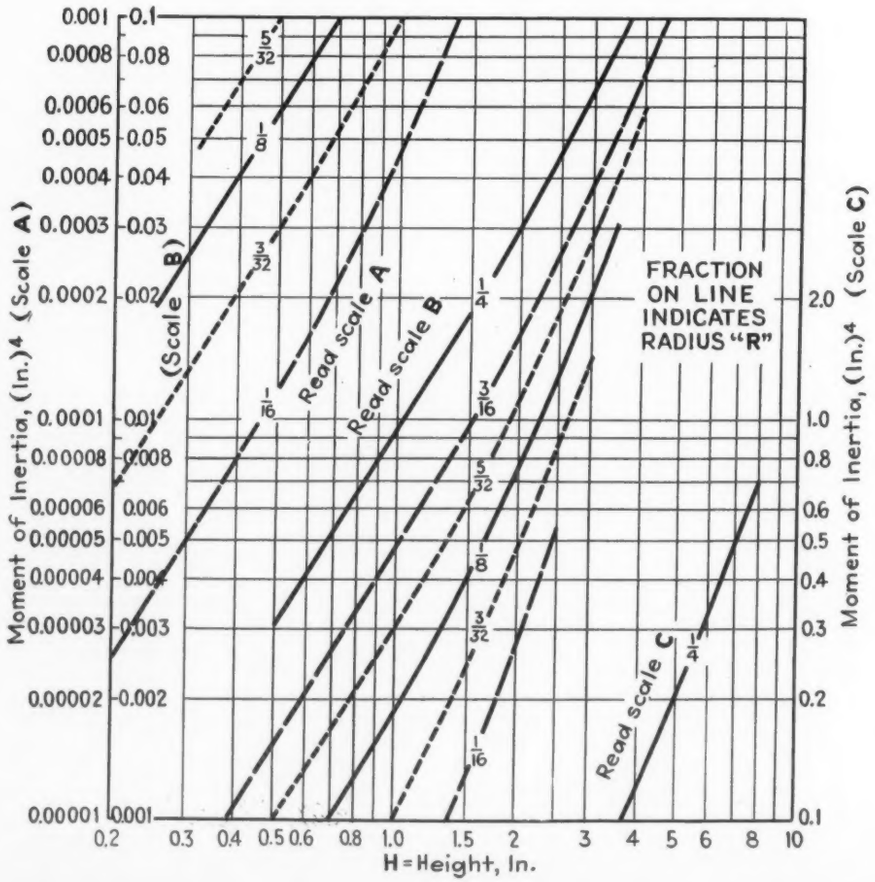


$$I_{xx} = 0.00003855\,H^4 + 0.0022231\,H^3R + 0.048056\,H^2R^2 + 0.46166\,HR^3 - 0.34732\,R^4$$



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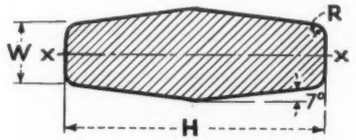
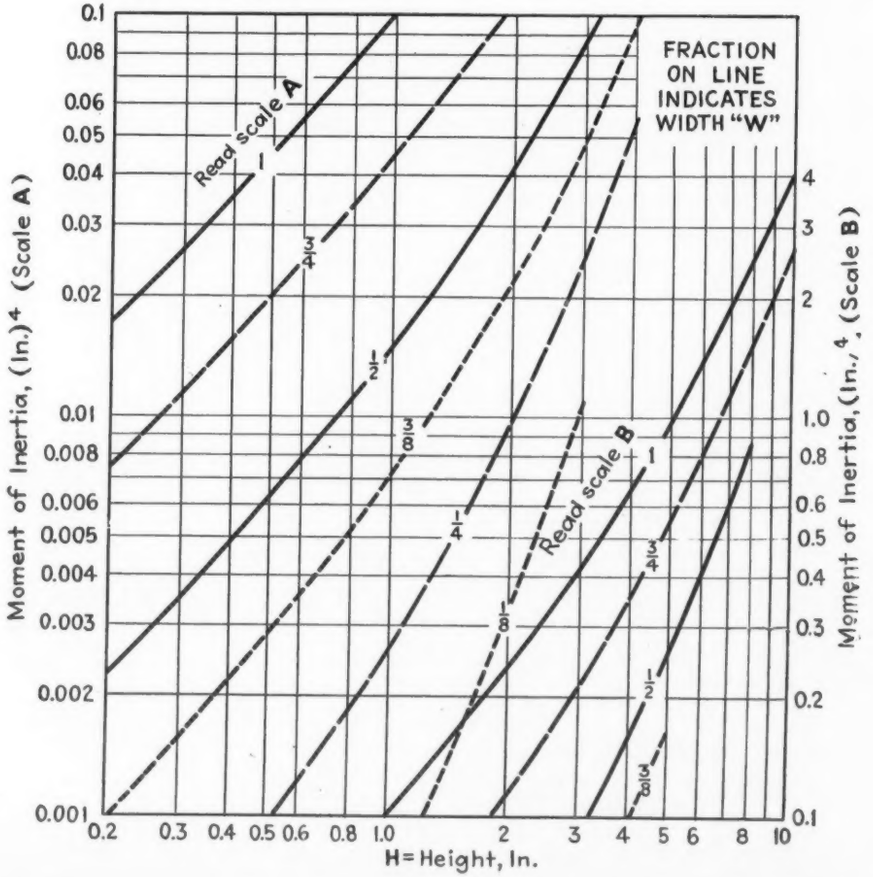


$$I_{xx} = 0.00004856\,H^4 + 0.001256\,H^3W + 0.01535\,H^2W^2 + 0.08333\,HW^3$$

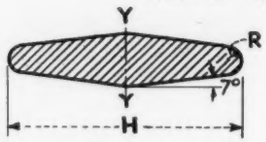


FORGING DESIGN DATA — MOMENT OF INERTIA ABOUT Y-Y AXIS

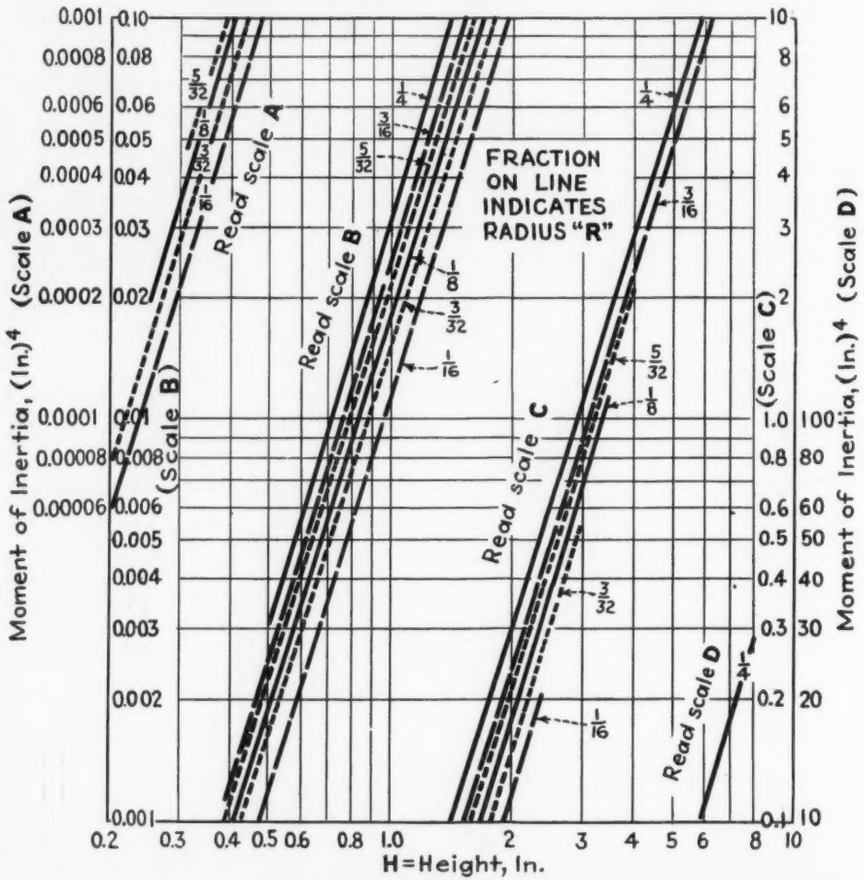
O. A. WHEELON

Methods Analysis Engineer, Douglas Aircraft Company, Inc.

Round Top Flange Section



$$I_{YY} = 0.00256H^4 + 0.14746H^3R - 0.16042H^2R^2 + 0.12376HR^3 - 0.04100R^4$$



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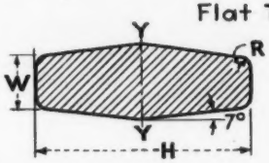
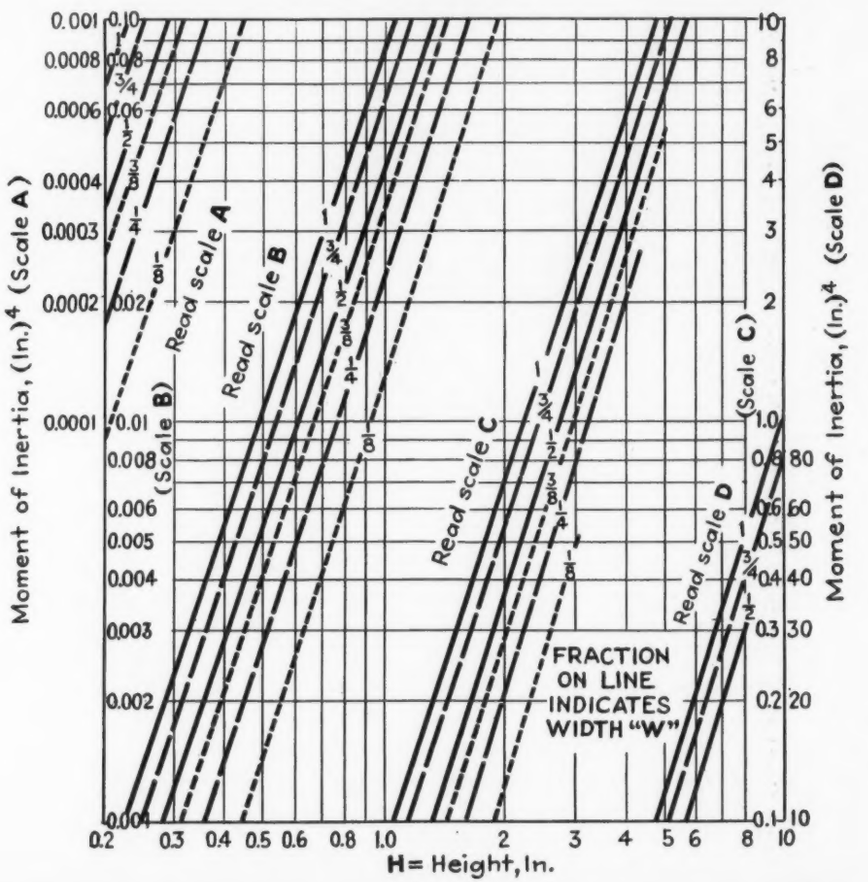


$$I_{YY} = 0.00256H^4 + 0.0833H^3W - 0.16042H^2R^2 + 0.12376HR^3 - 0.04100R^4$$

Curves plotted for first two terms only